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AFATL-TR-72-13

PWU-5/A MODULAR INTERNAL SPRAY SYSTEM

DEFENSE TECHNOLOGY LABORATORIES
FMC CORPORATION

TECHNICAL REPORT AFATL-TR-72-13

JANUARY 1972

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PWU-5/A Modular Internal Spray System

Larry R. Ramsauer

FOREWORD

This report has been prepared by the Defense Technology Laboratories (DTL) of FMC Corporation, San Jose, California, under Contract F08635-69-C-0213. Program monitors for the Armament Laboratory were Mr. Marshall G. Solomon (DLGZ) and Captain Harold L. Hebert (DLIF).

The design, development, fabrication, testing and delivery of the PWU-5/A Modular Internal Spray System was conducted from 7 July 1969 through 30 September 1971 by DTL under the direction of Mr. Atlee H. Bussey, Program Manager, and Larry R. Ramsauer, Project Engineer. Technical personnel assigned to the program were William P. Farris, David N. Singletary, Richard W. Triebel, and Forrest A. Hettinger.

This technical report has been reviewed and is approved.

Franklin C. Davies, Colonel, USAF
Chief, Flame, Incendiary, and Explosives Division

ABSTRACT

The PWU-5/A Modular Internal Spray System (MISS) has been designed and developed to fit ten cargo/utility-type aircraft, including the C-47, C-54, C-123, and C-130. The system was designed to disseminate herbicides, pesticides, and fertilizers in chemical solution, suspension, or slurry form at ground deposition rates from 3 ounces/acre to 3 gallons/acre with a minimum swath width of two times the applicable aircraft wing span. The system is completely self-supporting, requiring no aircraft power, and includes provisions for suction filling, agent recirculation/agitation, dissemination, system flushing, aircraft washdown, and emergency dumping of the full agent payload. The system used aerospace adhesive to secure all external hardware, allowing system installation with minimum aircraft modification. A complete C-123K MISS was installed and flight tested at Eglin Air Force Base, Florida. The system was subjected to the complete flight envelope and functioned as designed. Flight test results indicated that manual operation of the emergency dump took too long to initiate. The dump chute should be moved to the aft portion of the jump door to minimize emergency dump contamination, and the right-hand fuselage spray station should be capped off to eliminate fuselage spray contamination.

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SECTION I

INTRODUCTION

This report describes the work performed in the development of the PWU-5/A Modular Internal Spray System, designed to disseminate various chemical agents utilizing ten different cargo/utility-type aircraft.

Major effort was devoted to the design of a modular spraying system which would exploit the full payload capabilities of all applicable aircraft by using multiples of the modular components, allow for installation and removal at the organizational level without permanent modification to the aircraft, and permit spraying of a large variety of chemical agents over a wide range of deposition rates. Compliance with these requirements resulted in the use of a modular power unit and multiple modular 500-gallon-capacity tank units. All hardware attached to the aircraft skin (wing booms, etc.) was attached using adhesive to avoid metal cutting or welding. Emergency dumping was accomplished through the use of internal ducts, manifolded into a single duct, which exhausted at an open rear jump door.

To assure an optimized agent transfer system, a complete system flow model was built and tested.

This report contains a complete description of the PWU-5/A Modular Internal Spray System; a development history of each of the major subsystems and components; discussions of contamination and safety considerations; ground and flight testing results; and discussions of reliability, maintainability, and cost effectiveness. The appendices contain the stress analysis for the various system internal components. Analysis of the C-47, C-123, and C-130 external hardware and complete installation instructions are presented in the modification documents for these aircraft.

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SECTION II

SUMMARY

The detailed design requirements were defined in the contractual document. The design and development effort was directed at the complete system, including aircraft compatibility; material/agent compatibility; minimizing aircraft modification; internal tanks, power module, and agent transfer system; emergency dump, and sealed tank venting system; external wing booms, nozzles, and positive shut-off nozzle valves; operator and pilot controls; flow rate monitoring and control; contamination prevention; built-in ground support features including self-filling and draining, system flushing, and aircraft washing; reliability, maintainability, and supportability.

The PWU-5/A MISS was designed to be compatible with and exploit the full payload capabilities of the C-46, C-47, C-54, C-97, C-118, C-119, C-121, C-123, C-130, and C-131 aircraft. Each system uses a single power module; multiple tank modules; multiple standard wing boom, dump, and vent sections; and miscellaneous plumbing fittings. Due to the unique geometry of each aircraft, different length hoses and other special fittings are used for each installation. These special parts are kept to an absolute minimum, utilizing the modular concept to the fullest extent possible.

The agent transfer system contains all necessary controls and monitoring equipment to fill, mix, and disseminate chemical solutions, suspensions, or slurries. Dissemination rates may be varied from 2.5 to 600 gpm while controlling the flow rate to within ± 5.0 percent. This flow rate range permits all aircraft to meet the required 3-ounce to 3-gallon per acre ground deposition rates while maintaining an effective swath of at least two times the wing span of the applicable aircraft.

To minimize agent transfer system components and insure system effectiveness, a complete agent transfer system flow model was built and tested.

All system components were studied to reduce hardware costs while maintaining functional effectiveness.

The C-47, C-54, C-123, and C-130 aircraft were selected as primary, and complete PWU-5/A Modular Internal Spray Systems were designed, fabricated, tested, and delivered for the C-47, C-123, and C-130 aircraft.

The C-123K MISS was installed and flight tested at Eglin Air Force Base. The delivered C-130 system, to be used for Air Force flight testing, utilizes four tank modules instead of the eight tank modules normally installed in a C-130 aircraft. Complete system fitment tests for the C-47, C-123, and C-130 aircraft were made at NAS Moffett Field, California, to insure aircraft/system compatibility.

Material/agent compatibility studies were made to select compatible system materials at minimum cost.

Several prime system components were cycle tested to verify a minimum 5-year life. Flowmeter accuracy tests were performed as were functional tests of major hardware components.

SECTION III

DESCRIPTION

3.1 SYSTEM DESCRIPTION

The PWU-5/A is an airborne, modular, reusable system capable of disseminating defoliants, herbicides, pesticides, and fertilizers as chemical solutions, suspensions, or slurries. The system consists of a power module with a control panel, multiple agent reservoirs, an emergency dump system, wing booms and fuselage spray stations with positive shut-off nozzle valves, a sealed tank venting system, and miscellaneous piping and fittings. The system can be assembled in various combinations to fit the ten specified cargo-type aircraft. Figure 1 shows the C-123 MISS installation, which is a typical two-tank system. Larger aircraft use additional tanks. The C-130 uses eight tanks, four on each side of the power module. The C-54 uses four tanks, two on each side of the power module. The C-47 MISS installation is unique in that it uses two tanks, both on the same side of the power module.

The power and control module contains all necessary equipment for controlling filling, priming, recirculating, disseminating, emergency dumping, flushing, and draining the fluid system. The system is entirely self-supporting, requiring no aircraft power. System power is provided by an air-cooled, internal combustion engine which drives the main pump, an air compressor, and generates necessary electrical power. The control panel includes all gages and controls for complete system operation and monitoring. In addition, the aircraft pilot is provided with controls for both disseminating and emergency dumping.

The agent reservoirs have a usable capacity of 500 gallons each and include a filler cap, vent line, level sensors, inlet and outlet tubes, and an emergency dump valve.

The entire system is closed to insure no escape of agent or agent vapors inside the aircraft. The power module and tank modules have captive, retractable casters for mobility.

All nozzle stations have pneumatically actuated positive shut-off valves that prevent agent leakage at the nozzles when spraying is stopped. These valves are fail-safe; if the pneumatic actuation line fails, the valves continue to function as agent shut-off valves but will only seal against agent pressures less than 5 psig.

Minimal aircraft modification is assured by routing all external plumbing, the tank vent system line, and the emergency dump outlet line through the aircraft jump doors, and by bonding the external plumbing and wing boom mounting plates to the aircraft with an aerospace adhesive.

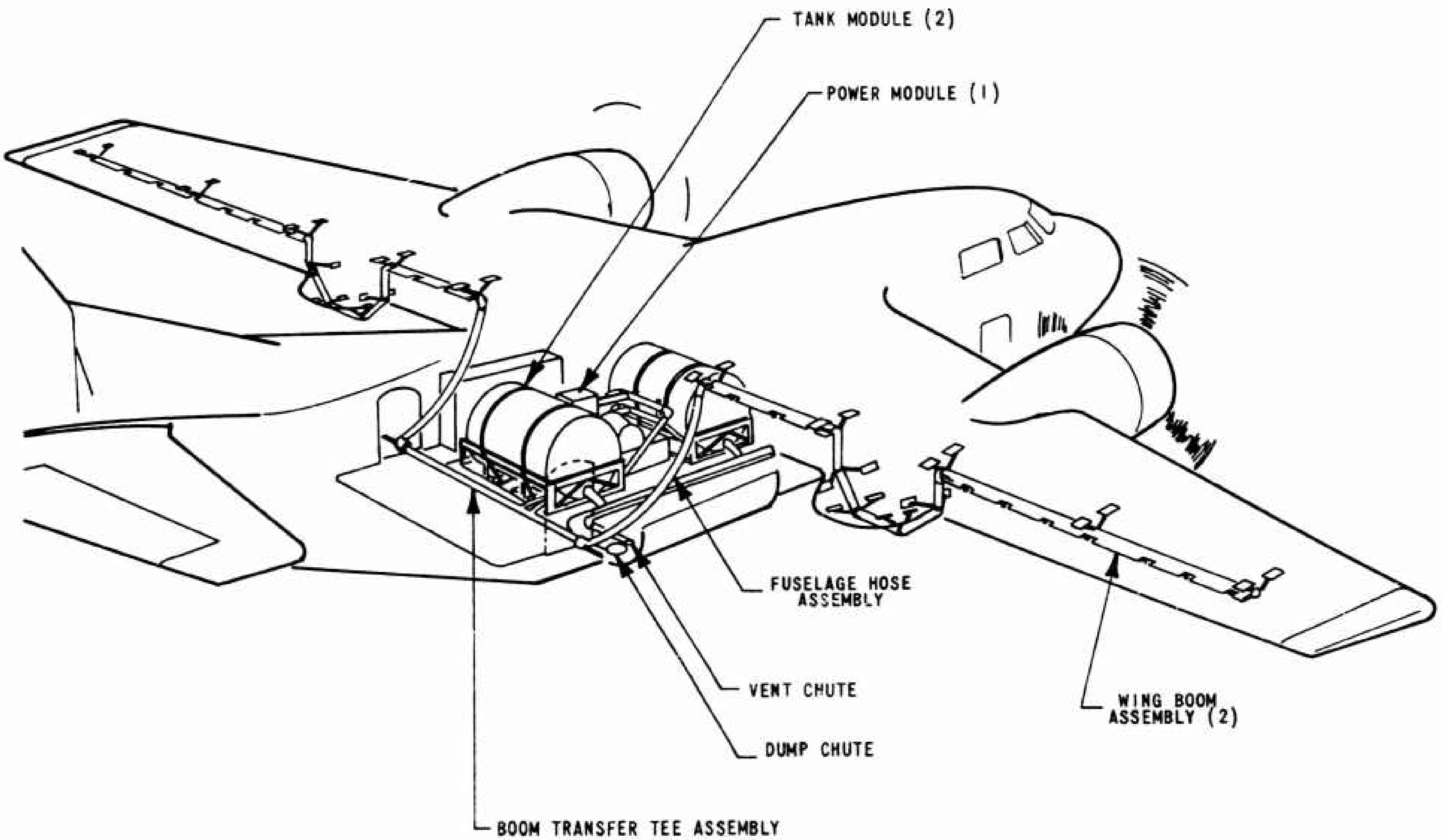

Figure 1. C-123 Modular Internal Spray System Kit No. 4373716

3.2 SYSTEM PARAMETERS

The parameters given in Table I apply to the complete MISS system as installed in the ten specified aircraft. Parameters of the individual system modular components are discussed in paragraph 3.3.

3.3 COMPONENT DESCRIPTION

3.3.1 <u>Agent Transfer System</u>

The agent transfer system consists of all components which transfer agent from the tanks to the wing booms. The transfer system is shown in schematic form in Figure 2, and the power module piping portion of the system is shown in Figure 3 for cross-reference.

The system uses twin 4-inch suction lines to draw agent from the tanks. These 4-inch suction lines merge and feed the centrifugal pump. The pump output may be directed four ways; (1) recirculated back to the tanks, (2) disseminated through the high volume spray system, (3) disseminated through the low volume spray system, (4) drained through the power drain port.

The amount of recirculation is controlled by a butterfly valve, and recirculation may continue during spraying.

Both the high and low volume spray systems have turbine flowmeters for accurate flow rate monitoring. Each system also has its own throttle valve to allow adjustment of flow rates. The low volume system has a fine mesh strainer to filter out foreign matter, which may tend to plug the extremely small orifices of the low volume spray nozzles.

The MISS agent transfer system is self-supporting in that it includes provisions for self-priming, suction filling, and power draining. Self-priming is accomplished by using an air eductor which draws agent through the ground fill hose and the centrifugal pump. Once the centrifugal pump is primed, it becomes the pumping source for suction filling.

During power draining, the centrifugal pump transfers agent from the tanks through the appropriate ground support hose.

The agent reservoirs are equipped with motor-driven vent valves, which automatically open when the desired function switch is thrown on the control panel (i.e., pump prime, fill, drain, etc.).

TABLE I. PWU-5/A MODULAR INTERNAL SPRAY SYSTEM PARAMETERS

SMALLEST SYSTEM	2 TANKS, 1 POWER MODULE
LARGEST SYSTEM	8 TANKS, 1 POWER MODULE
CAPACITY	0 - 4,000 GALLONS (MAX.)
DISSEMINATION RATE	2.5 GPM (MIN.) 600 GPM (MAX.)
FLOW RATE MONITORING ERROR	LESS THAN ± 5.0% FROM 2.5 TO 600 GPM
SUCTION FILLING RATE USING 50-FOOT, 2-INCH DIAMETER HOSE	
WITH WATER	145 GPM 57-INCH LIFT 125 GPM 16.5-FOOT LIFT
WITH 55-GALLON DRUM SUCTION PROBE ATTACHED, WITH WATER	75 GPM 57-INCH LIFT 50 GPM 16.5 FOOT LIFT
EMERGENCY DUMP TIME	LESS THAN 45 SECONDS FOR 1/2 AGENT PAYLOAD FOR ALL AIRCRAFT
ELECTRICAL SYSTEM	28 VDC, ALL CIRCUITS INDIVIDUALLY PROTECTED BY BREAKERS
NOZZLE VALVE	3/4-INCH PNEUMATIC DIAPHRAGM
DUMP VALVE	4-INCH BUTTERFLY, PNEUMATIC WITH MANUAL OVERRIDE
SPRAY VALVE	3-INCH BUTTERFLY, PNEUMATIC
SELF-SUPPORTING FEATURES	NO AIRCRAFT POWER REQUIRED SUCTION FILL POWER DRAIN TANK WASHING NOZZLE PROBE AIRCRAFT WASHING GUN RECIRCULATION MIXING

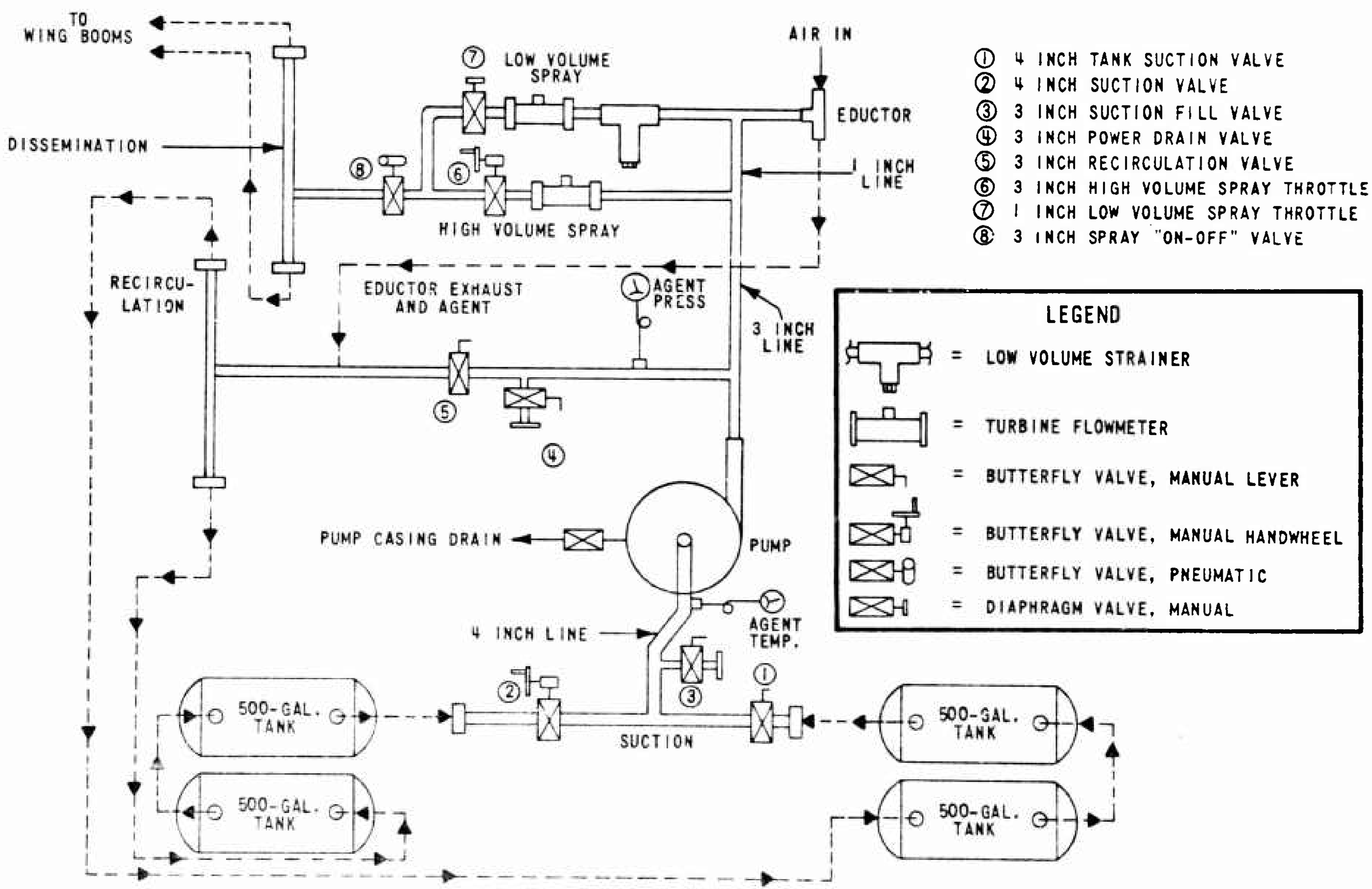

Figure 2. Agent Transfer System Schematic

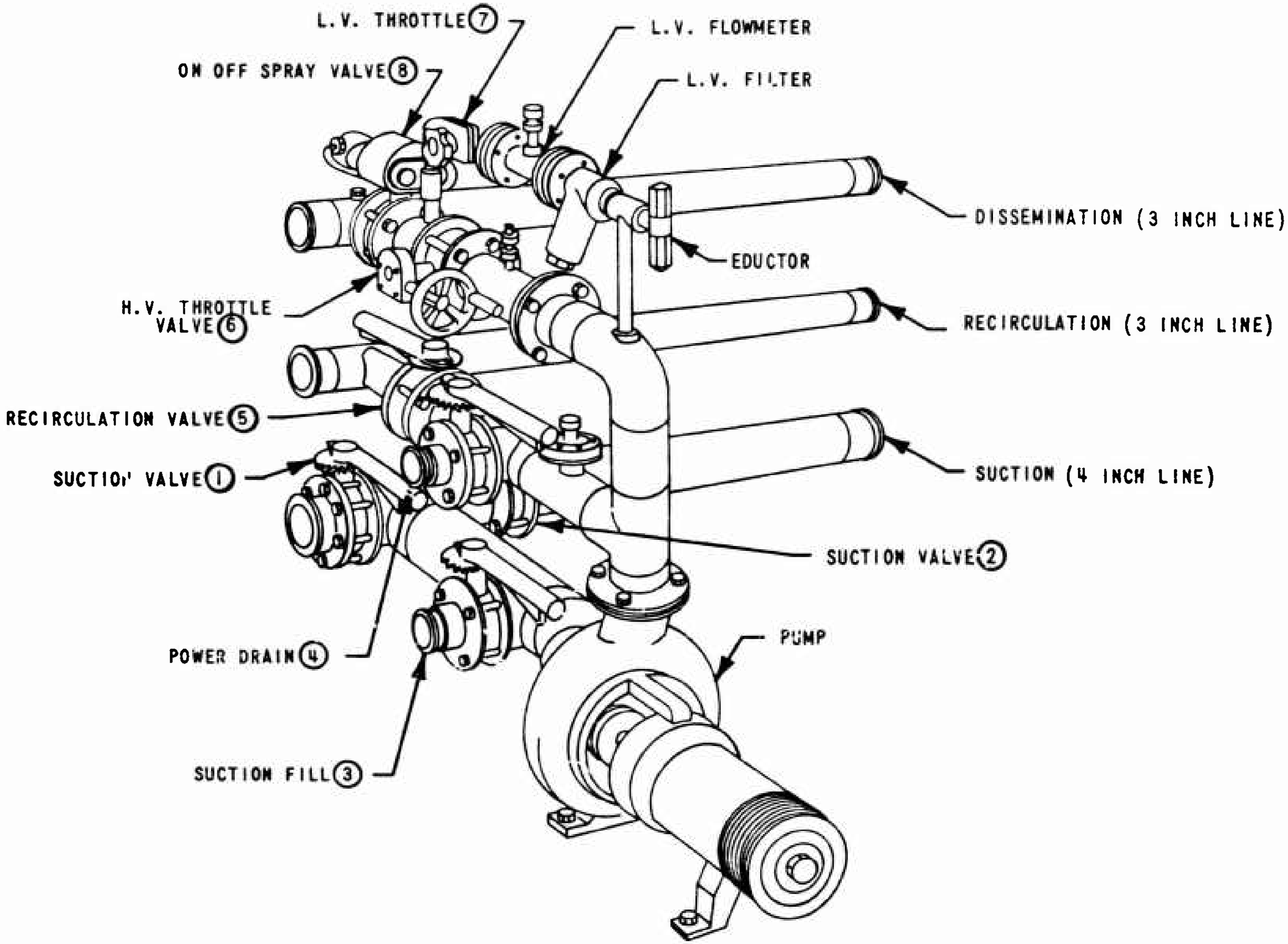

Figure 3. Agent Transfer System Power Module Piping

3.3.2 Pneumatic System

The pneumatic system generates, stores, and directs compressed air for control of various system functions, as shown in Figure 4.

Compressed air is generated by a single 7.4-CFM two-cylinder air compressor, which is belt-driven by the Packette PE90-7 internal combustion engine. The compressor is equipped with a governor and unloader assembly which allows the compressor to cut-out and free-wheel after a preset air reservoir pressure has been reached. When the air reservoir pressure drops below a certain level, the air compressor automatically cuts back in and supplies compressed air. When free-wheeling, the compressor continues to cycle but without compressing air. Normal range between cut-in and cut-out pressure is 17-22 psig. The cut-out pressure is adjusted to 130 psig for use with the PWU-5/A MISS.

Compressed air is stored in two 1200-cubic-inch primary reservoirs and a single 634-cubic-inch emergency dump reservoir. The emergency dump reservoir supplies air through a filter-regulator set at 100 psig and 4-way solenoid valve to the emergency dump valves on the tank modules. The emergency dump air reservoir is isolated from the primary air reservoirs by a check valve so that the emergency dump air supply cannot be depleted except by actuation of the emergency dump system. The emergency dump air system can, however, utilize the primary air supply when the emergency air supply pressure falls below the primary air supply pressure. All three air reservoirs are equipped with drain petcocks, and both the primary and emergency air systems employ safety valves to prevent excessive pressure build-up due to any system malfunction. Both the primary and emergency air supplies are monitored by individual pressure gages.

The primary air supply passes through a filter-regulator set at 60-80 psig and supplies air for the spray valve, eductor, wing boom purge, and the wing boom nozzle diaphragm valve air pressure regulator. Both the eductor and wing boom purge air supplies are controlled with 2-way solenoid valves and are protected from spray agent by check valves. Air supplied to the eductor creates a vacuum in the agent transfer system piping for priming the centrifugal pump. The wing boom purge function allows air to pass through the external aircraft plumbing and out of the spray nozzles, purging agent from the wing booms. The nozzle diaphragm valve air supply utilizes a regulator to maintain pressure at 40 psig and a 3-way solenoid valve to control air direction. Air is supplied to the nozzle valves at all times when not spraying and is exhausted when spraying.

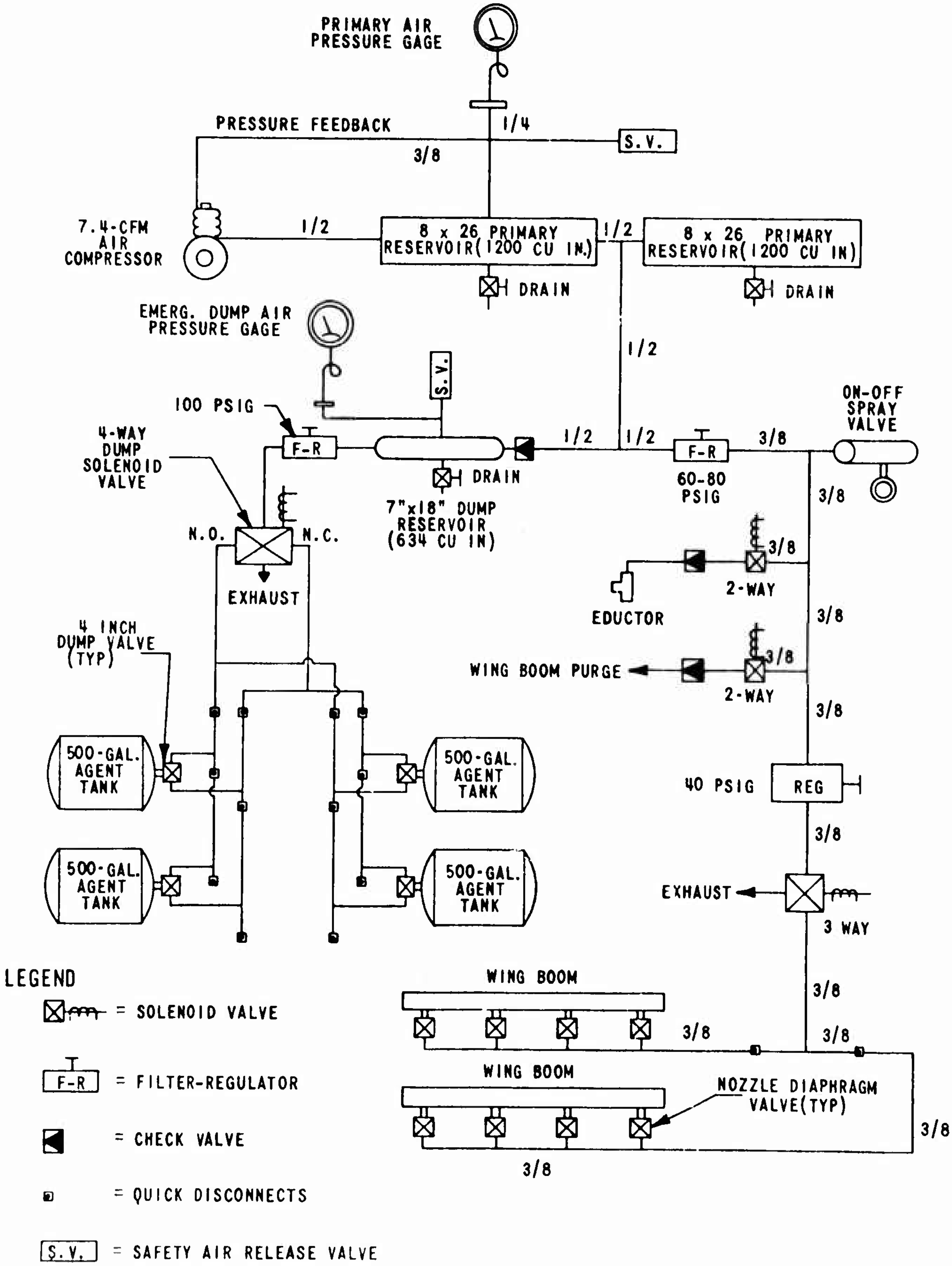

Figure 4. Pneumatic System Schematic

3.3.3 Power Module Assembly

The power module assembly is the heart of the PWU-5/A MISS and contains all necessary equipment to transfer, monitor, and control the spray agent. The power module incorporates an agent transfer system, pneumatic system, and electrical system. Figures 5, 6, 7, and 8 show the major power module components. The power module assembly measures 51-1/4 inches from front to back by 60 inches wide by 51 inches high. Approximate dry weight is 2000 pounds.

3.3.3.1 Frame

The frame is a structural aluminum weldment and has retractable castors, lifting jacks, engine heat deflector, forklift slots, belt guards, and tie-down eye bolts. The castors are held in the extended or retracted position with captive ball-lock pins, and the lifting jacks are used to raise or lower the front and back sides of the power module when extending or retracting the castors. The entire frame is coated with heavy-duty industrial epoxy paint.

3.3.3.2 Engine

The engine is 110-hp piston-driven, air-cooled, four-cylinder, four-stroke gasoline engine. It is a PE90-7 Packett engine produced by Continental Motors Corporation, FSN 2805-633-6689, and is currently in the Air Force inventory as the power source for several types of ground support equipment.

To drive the pump and air compressor, a 0.75:1 reduction gear housing (FSN 2805-960-1916) is used. This provides a single pad power take-off to which a splined stub shaft is attached with an outboard bearing to support the main drive pulleys. Two sets of four each 3V belts drive the pump; a single 3V belt drives the air compressor.

On the opposite end of the engine from the power take-off, a load-sensing governor and a 28V, 50-ampere generator are mounted on power take-off pads provided for them.

The dual exhaust pipes are manifold into a single pipe exhausting upwards. A commercial spark arrestor is mounted to the exhaust pipe. Gasoline is supplied to the engine by a separate tank and connected with drip tight quick-disconnect fittings.

3.3.3.3 Centrifugal Pump

The centrifugal pump is a 316 stainless steel chemical process pump with TFE mechanical seals. It is constructed to AVS size A70 envelope with a 10.0-inch casing and a 9.5-inch open impeller. The suction port is 4.0-inch diameter and discharge is 3.0-inch

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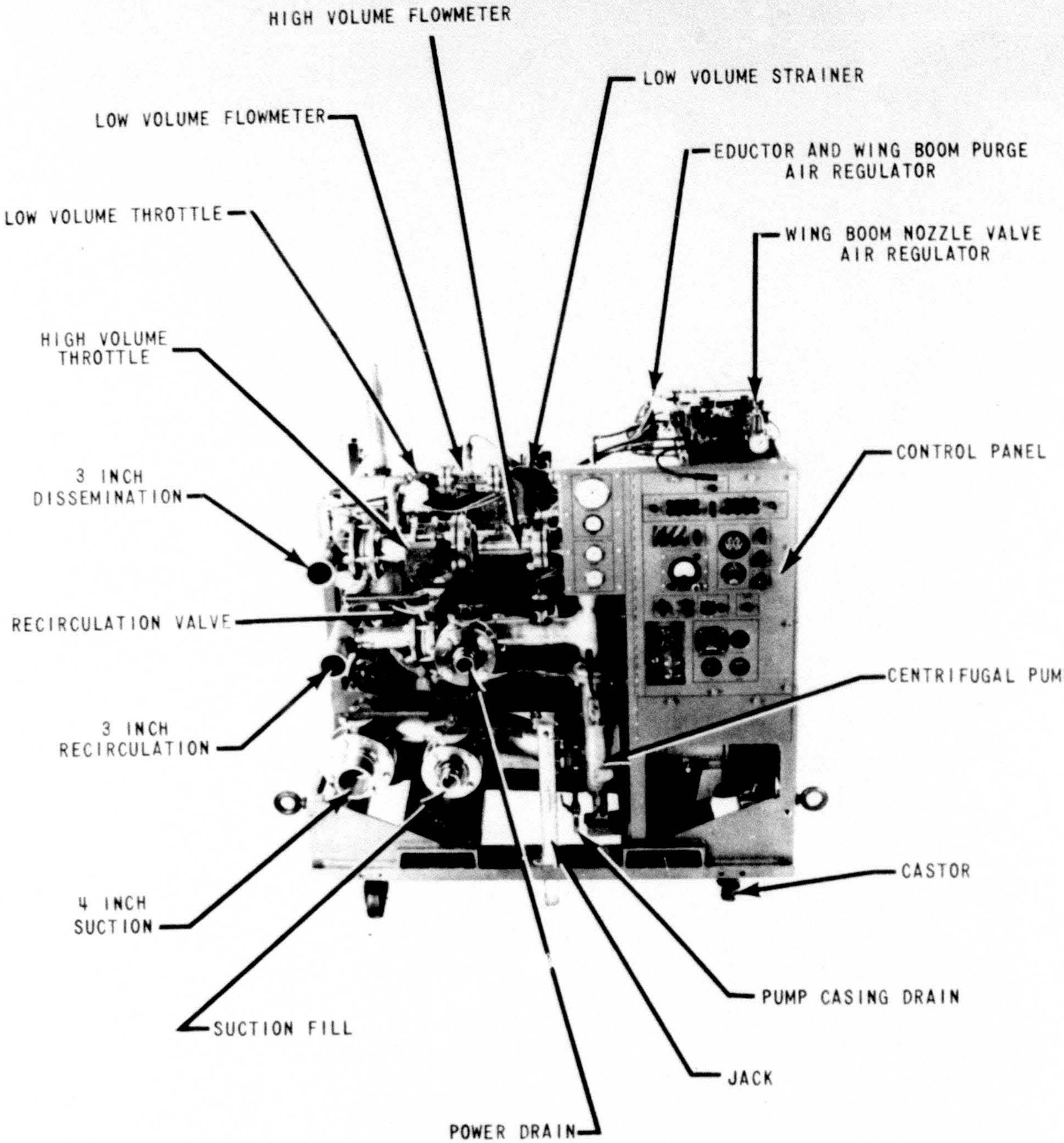

Figure 5. Power Module Assembly
(Front View)

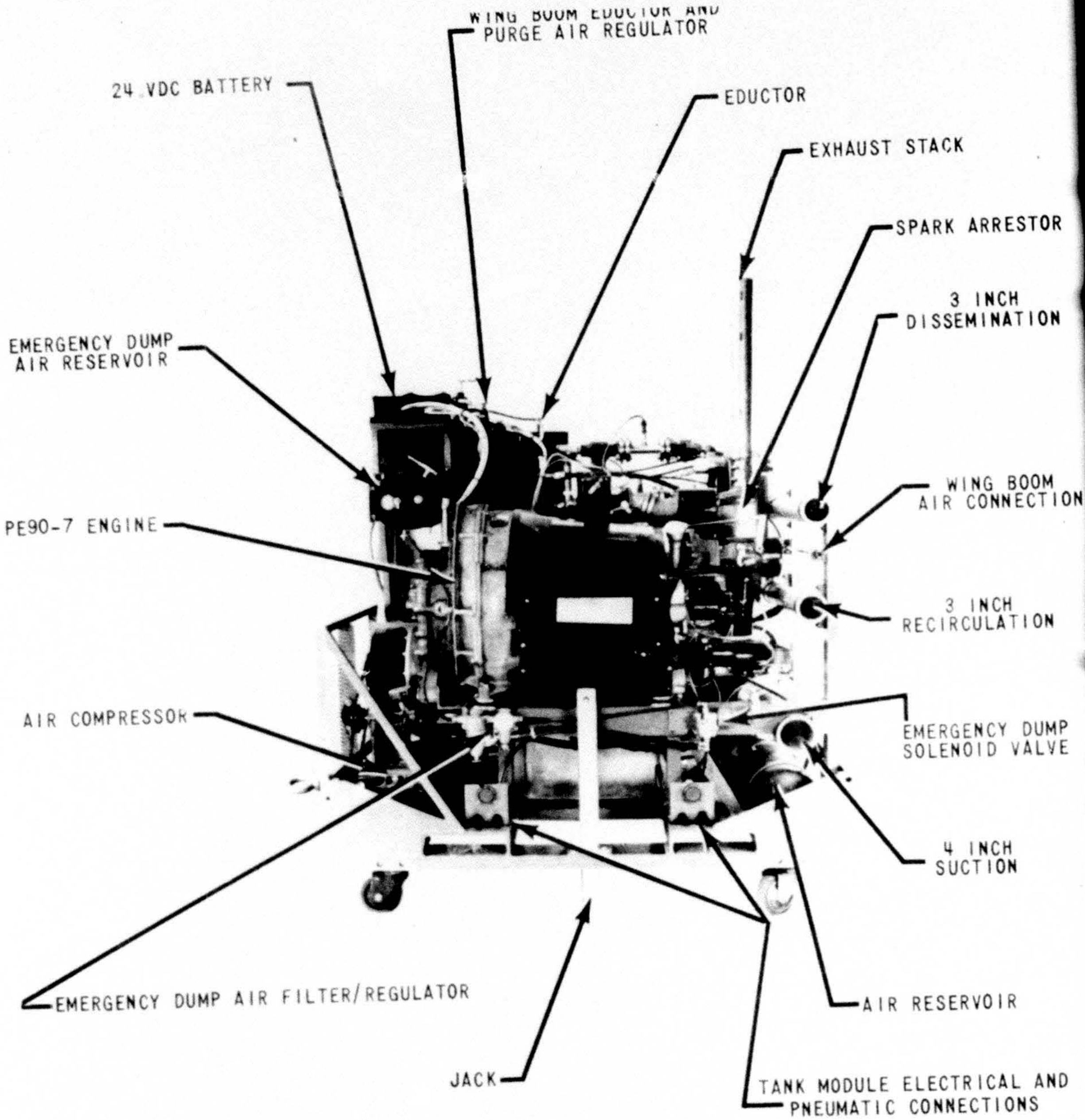

Figure 6. Power Module Assembly (Back View)

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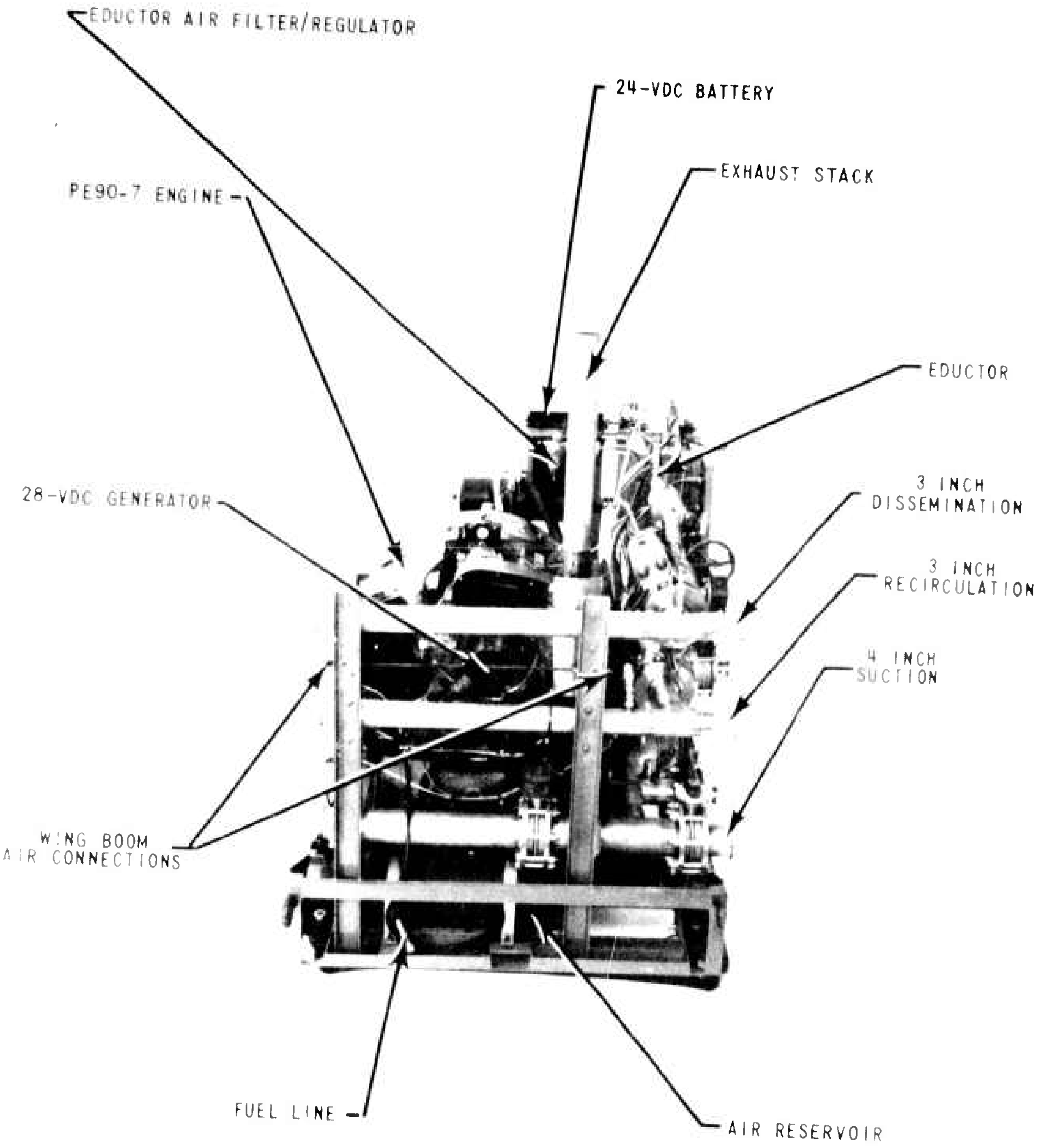

Figure 7. Power Module Assembly (Left View)

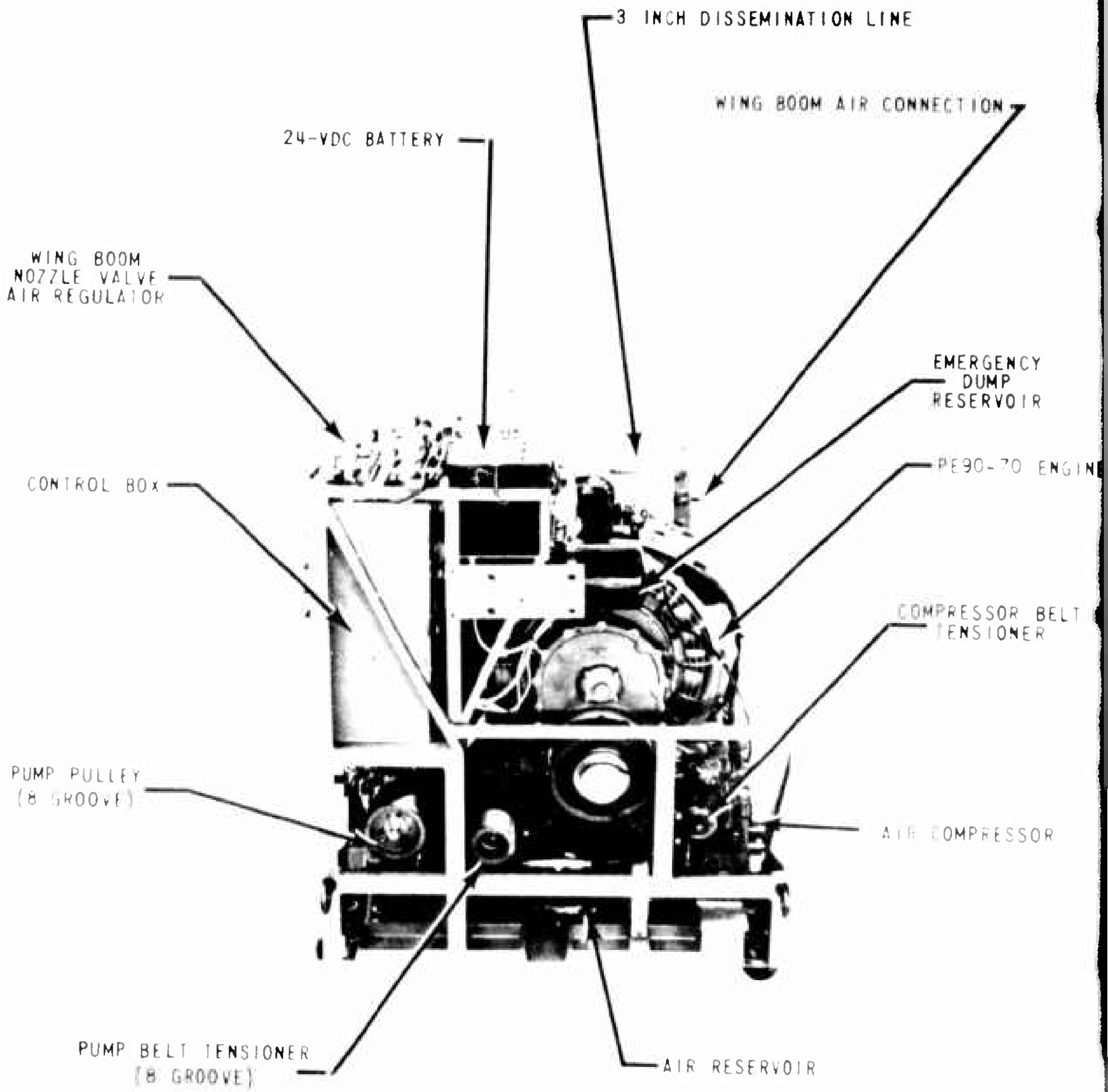

Figure 8. Power Module Assembly (Right View)

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diameter; both ports are fitted with ASA 150-pound drilled flanges. The casing has a 3/8-inch drain port. Pump bearings are oil lubricated, and the mechanical seals are pressure lubricated with a spring-type grease cup. The pump is designed to handle slurries and highly viscous agents as well as highly corrosive chemicals.

3.3.3.4 Air Compressor and Air Tanks

The air compressor is a reciprocating, power-driven, air-cooled, self-lubricated design used as a source of compressed air in the air brake system of military and commercial wheeled vehicles. Its rated delivery is 7.4 CFM of free air at 100 psig nominal.

The compressor is belt-driven off the engine power take-off shaft. A pressure unloader allows the compressor to free-wheel when the air tanks have been pressurized to 130 psig and cuts the compressor back into the system when the pressure falls to approximately 90 psig.

The air tanks are cylindrical in shape and are secured to the power module with strap brackets.

3.3.3.5 Agent Valves

The 3-inch and 4-inch-diameter butterfly valves are aluminum body with TFE sleeves and seals and 316 stainless discs. The butterfly valves are gearwheel, lever, and pneumatically actuated. The low volume spray throttle valve is a TFE diaphragm/stainless steel valve.

3.3.3.6 Piping

The 3-inch and 4-inch-diameter piping is 304 stainless and a combination of schedule 5 pipe and 0.065-inch wall tubing. All piping is welded and passivated. Piping connections are made with corrosion weight flanges, sanitary fittings, or quick disconnect fittings (used for ground support hose connections). The low volume spray system is 1-inch, schedule 40, 304 stainless screwed pipe.

3.3.3.7 Solenoid Valves

The solenoid air valves are commercial 24 Vdc brass.

3.3.3.8 Pneumatic Actuator

The pneumatic actuator on the main spray valve is an aluminum body, twin piston-type actuator.

3.3.3.9 Eductor

The eductor is 304 stainless and obtains a maximum suction of 27 inches of mercury at 80 psig input air pressure. Air consumption at 80 psig is about 11.4 SCFM. At 60 psig, air consumption is 9.0 SCFM, and a suction of 25 inches of mercury is obtained.

3.3.3.10 Flowmeters

Two flowmeters are used: 3-inch-diameter high volume (up to 600 gpm) and 1-inch-diameter low volume (2.5 to 60 gpm). The meters are turbine-type, constructed of stainless steel with carbide bearings. (The prototype MISS flowmeters were supplied with TFE bearings due to the unavailability of carbide.) The meters are fitted with ASA 150-pound drilled flanges.

3.3.4 Tank Module Assembly

The tank module assembly is shown in Figures 9 and 10. The assembly measures 48 inches wide by 72 inches long by 64 inches high and weighs approximately 670 pounds dry. Agent capacity is 500 gallons.

3.3.4.1 Tank

The tank is constructed of 14-gage 304 stainless steel. The tank ends are ASME low crown flanged and dished heads. Access into the tank is through a 10-inch by 19-inch manhole in the tank top. The manhole cover has a fill cap, cup-type strainer under the fill cap, liquid level transmitter assembly and 2-inch pipe vent line. Agent slosh is controlled by a single vertical internal baffle of perforated sheet, which covers the lower half of the tank and is curved for strength. One tank end has three 3/4-inch—14 NPT plugged openings to provide for possible instrumentation during testing. Two of these openings were used for a visual liquid level indicator designed for water testing only, since the indicator materials are not agent compatible. Two 4-inch agent pick-up pipes are provided on the bottom of the tank, one at each end. Attached to these pipes with sanitary fittings are 90°, 4-inch elbows. A 4-inch dump valve is located on one lower end of the tank.

3.3.4.2 Cradle

The cradle is a weldment of structural aluminum, coated with heavy duty industrial epoxy paint, and secures the tank with two band straps. Castors are provided on each corner of the cradle, retained with ball-lock pins, and can be easily extended or retracted after lifting the end of the tank module assembly with the captive jacks provided. Forklift tubes are located on the cradle side. Eye bolt tie-downs are located at each cradle corner.

3.3.4.3 Electrical Junction Box

The electrical junction box is secured to the top of one forklift tube. Extending from the electrical junction box is a cable which connects to either an adjacent tank or the power module, as shown in Figure 11.

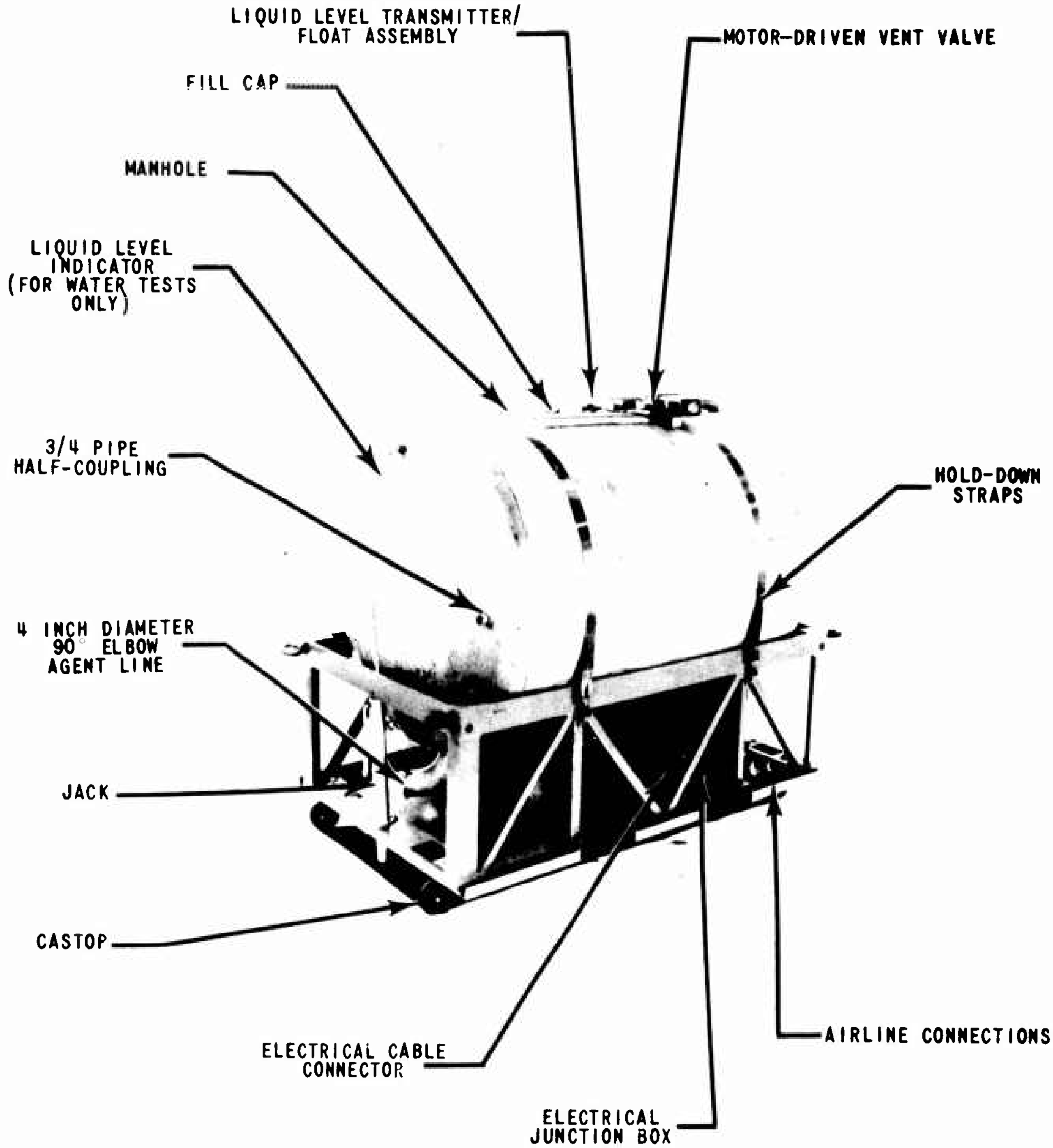


Figure 9. Tank Module Assembly
(Side View)

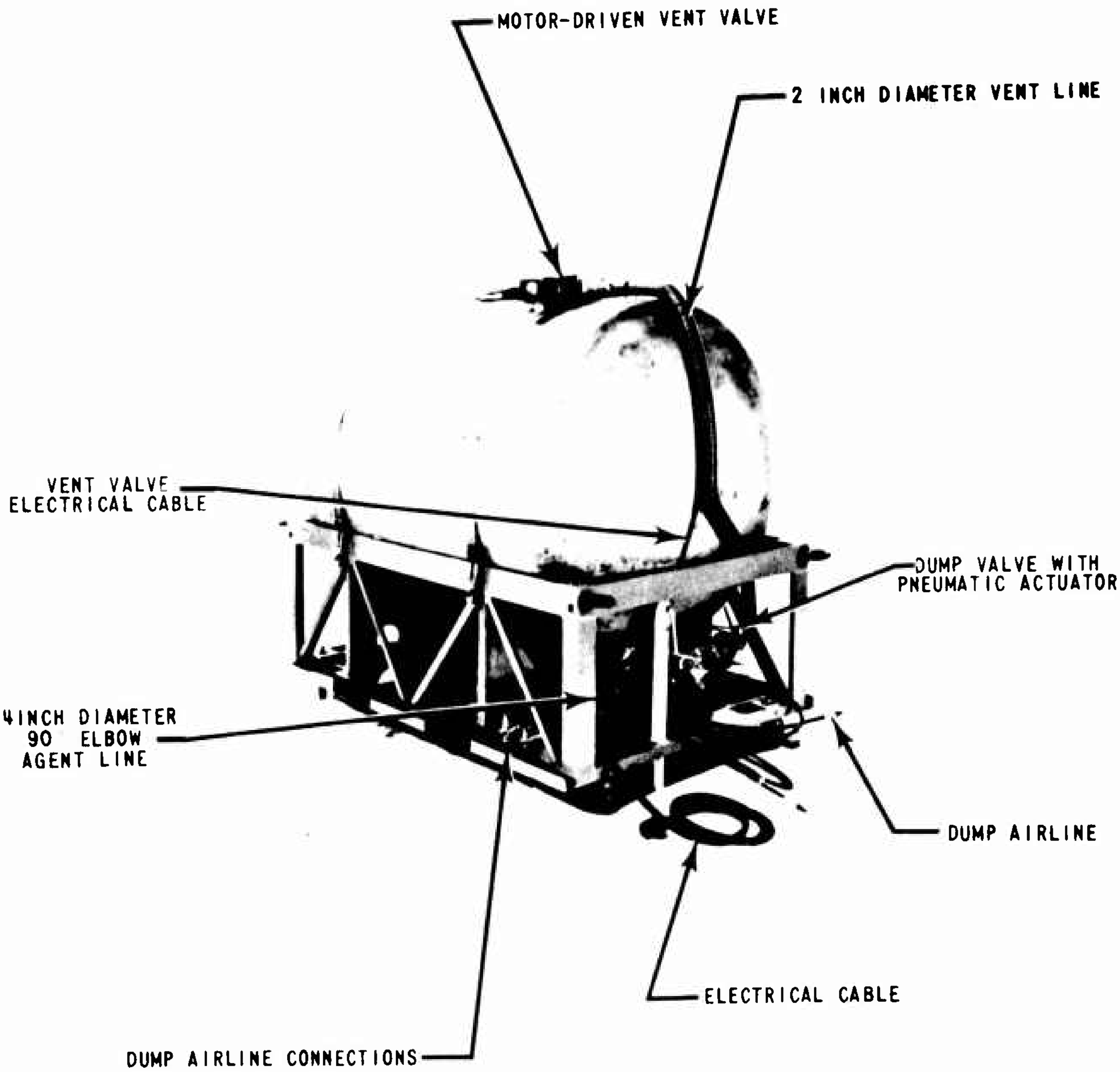


Figure 10. Tank Module Assembly (End View)

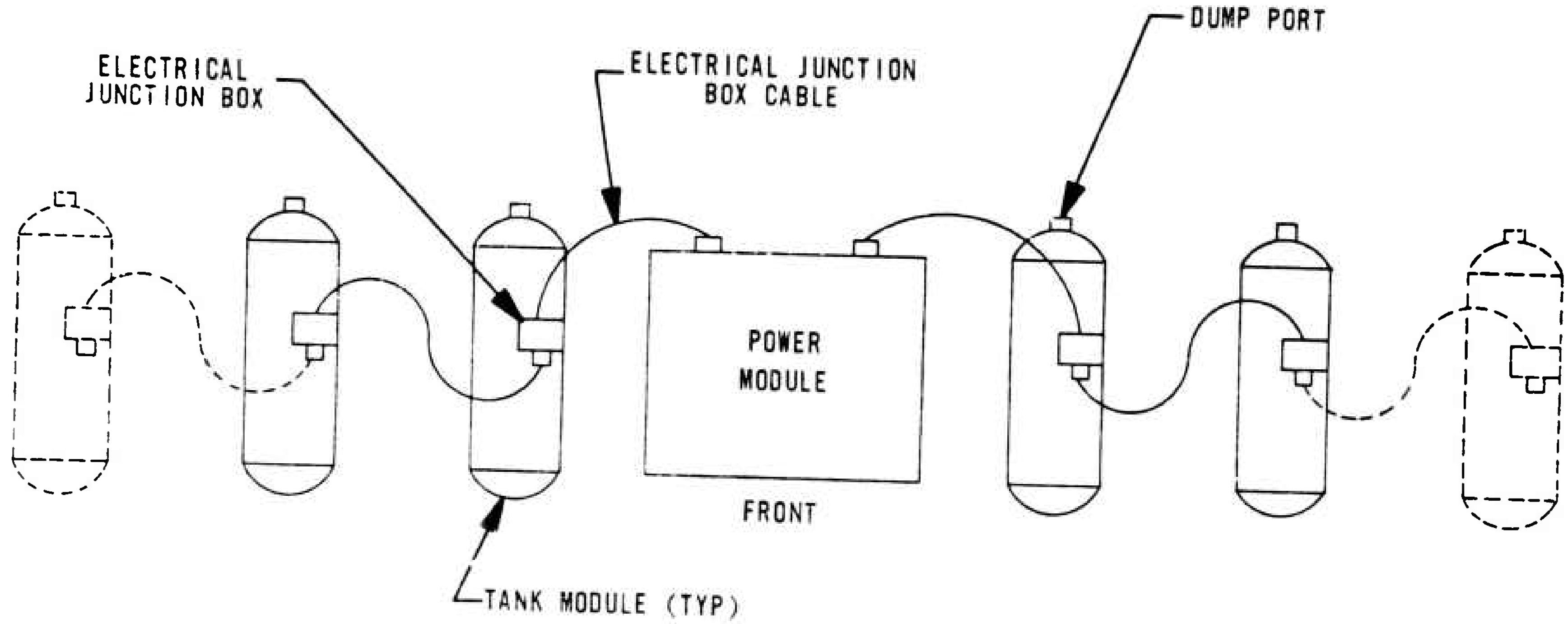


Figure 11. Tank Module Assembly Electrical Cable Connection

3.3.4.4 Dump Valve

The dump valve, located at the bottom of one tank end, is a 4-inch butterfly with TFE sleeve, 316 stainless disc, and aluminum body. The valve is actuated by a twin-piston pneumatic actuator, which is equipped with a handle for manual operation. The actuator uses air to open and close the valve and; therefore, air pressure must be relieved before manual valve operation is possible. The dump valve air lines are connected in exactly the same sequence as the electrical junction box cable (Figure 11). The air lines on the tank module nearest the power module are connected to the power module, the next outermost tank module air lines are connected to the tank nearest the power module, etc. The two dump valve air lines are different sizes, eliminating the possibility of incorrect connection.

3.3.4.5 Vent Valve

The vent valve is a 2-inch brass ball valve with TFE seats. It is driven with a 28-Vdc motor actuator which provides feedback to the power module control panel to indicate whether the valve is open or closed.

3.3.4.6 Fill Cap and Strainer

The fill cap is 304 stainless with a fluorosilicone gasket. It is spring-loaded and will seal up to about 15 psig internal tank pressure. Located below the fill cap is a removable stainless steel strainer to filter out foreign matter if agent is poured directly into the tank.

3.3.4.7 Liquid Level Float/Transmitter Assembly

The liquid level transmitter is a sealed resistive-type level indicator made of nickel-plated brass, stainless steel, and TFE. It is bolted to the manhole cover and supported at the bottom of the tank by a short vertical tube which forms a slip-joint. This method of connection allows the tank to expand and contract due to temperature changes, etc., without damaging the float assembly. When the float reaches the top of its travel during ground filling, it trips an internal switch which closes the tanks vent valve, preventing agent from being pumped through the vent line. When all tanks in any size PWU-5/A MISS have been filled in this manner, the power module engine magneto is grounded, stopping the engine to prevent overpressurization of the tanks.

3.3.5 Power Module Controls and Instrumentation

The power module control panel is shown in Figure 12. It contains all instrumentation and remote controls for the PWU-5/A MISS. All indicator lights are the press-to-test type and can be dimmed by

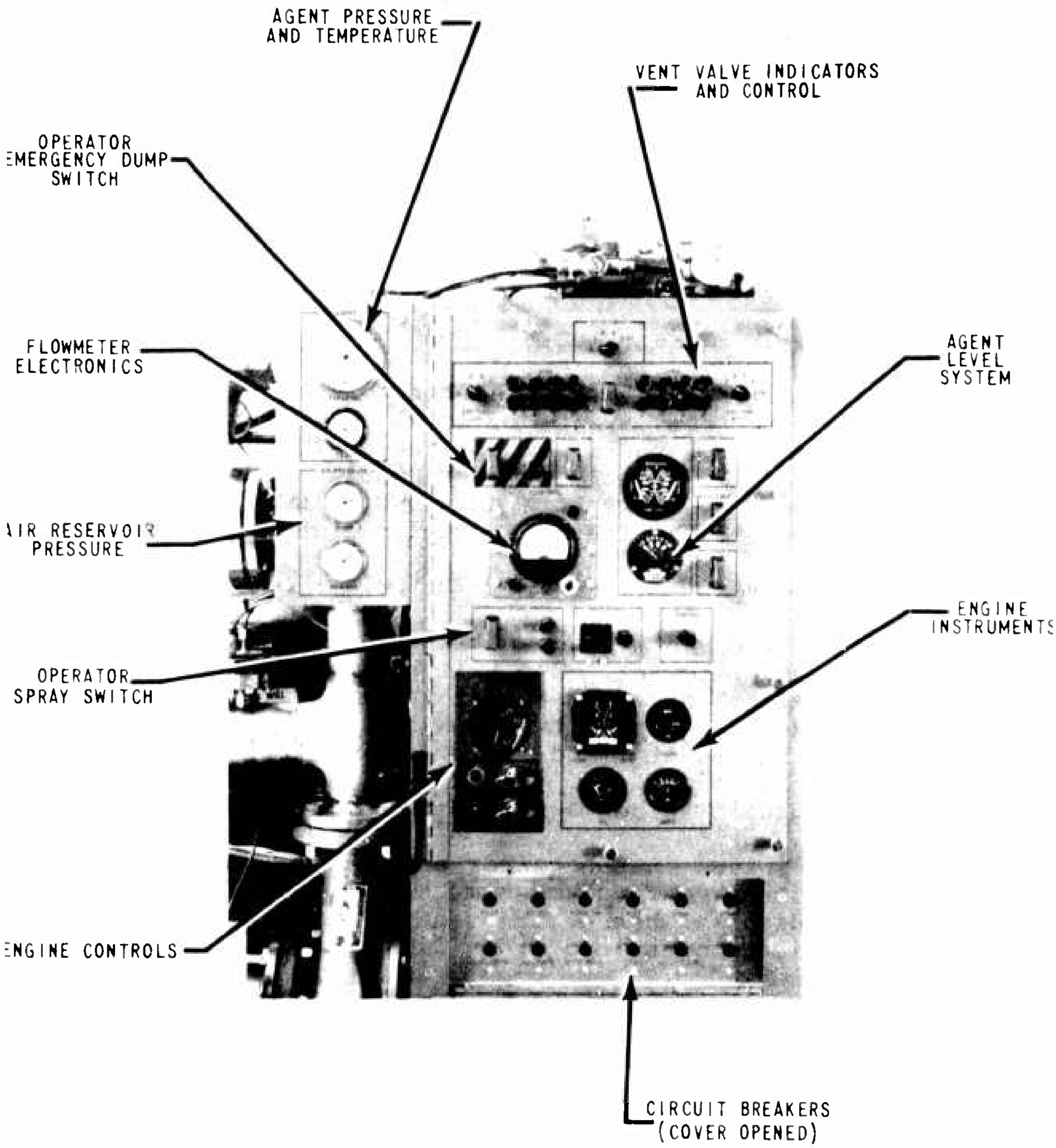


Figure 12. Control Panel

rotating. The control panel is hinged for easy access to the control box immediately behind the control panel. The control box contains the majority of the system's electrical equipment.

3.3.5.1 Agent Temperature and Pressure

The agent temperature and pressure gages are located at the upper left-hand corner of the control panel. Agent pressure is read at the centrifugal pump output and agent temperature at the pump intake.

3.3.5.2 Air Pressure

Two air pressure gages are located below the agent temperature and pressure gages. The upper gage reads the air pressure in the emergency dump reservoir, and the lower gage reads the pressure in the primary air reservoirs.

3.3.5.3 Number of Tanks

The switch at the top center of the control panel is used to set the system for the total number of tanks in the system. For all systems (2, 4, 6, or 8 tanks) except the C-47, the tanks are located symmetrically about the power module. The C-47 MISS installation uses two tanks both on the same side of the power module and therefore requires a special switch position.

3.3.5.4 Vent Valves

Figure 13 shows the vent valve control display and how it relates to the MISS tank placement. The switches marked "End Tank Left" and "End Tank Right" are used to set the system electronics for the correct end tank. For a two-tank symmetrical system, the switches would be set at 1 and 2; for a four-tank system, they would be set at 3 and 4, etc. The C-47 has special switch positions because it is not a symmetrical system.

The vent valve switch in the center of the vent valve panel opens and closes all tank vent valves simultaneously. Each tank has indicators to display whether its vent valve is open or closed. Red lights indicate open, and green lights indicate closed.

3.3.5.5 Dump

The dump switch opens all tank vent valves and dump valves, simultaneously. This switch is in parallel with the pilot's dump switch so that either the operator or pilot can start and stop the dump sequence. (The same switch must be used to both start and stop the dump operation.)

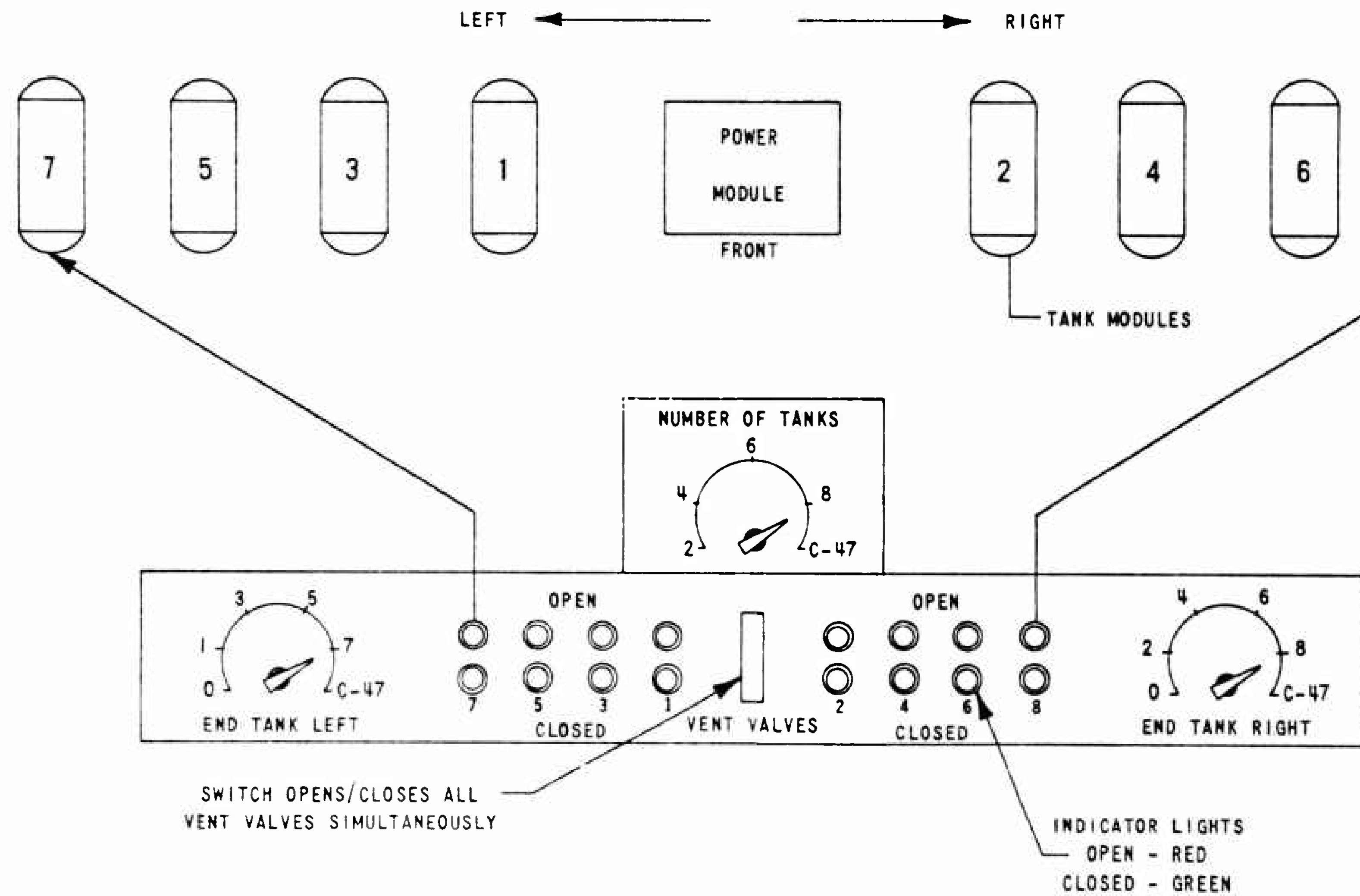


Figure 13. Vent Valve Control Schematic

3.3.5.6 Fill

The fill switch opens all tank vent valves for ground filling using the power module suction fill function. As each tank is filled, its vent valve automatically closes. When all tanks are filled, the engine magneto is grounded, stopping the engine and preventing overfilling the tanks. Turning the fill switch off allows the engine to be restarted. If the tanks are not filled full when ground filling is terminated, turning off the fill switch will close all tank vent valves.

3.3.5.7 Pump Prime

The pump prime switch supplies air from the primary air reservoirs to the eductor for priming the pump when the system is dry and opens the end tank vent valves to allow venting of the eductor exhaust air through the recirculation line and the end tank vents.

3.3.5.8 Air Purge

The air purge switch supplies air from the primary air reservoirs to the 3-inch dissemination line just after the main on-off spray valve. The air purge switch will not function unless the main on-off spray valve is closed, preventing the possibility of blowing air back through the system and into the tanks.

3.3.5.9 Drain

The drain switch opens the end tank vent valves only. This allows sequential draining of the tank modules.

3.3.5.10 Agent Capacity System

The agent capacity system includes a twin opposed needle indicator with each needle reading 0-500 gallons, and a four-position selector switch marked 1-2, 3-4, 5-6, 7-8. With the selector switch in the 1-2 position, the agent capacity of tank number 1 is displayed on the left needle indicator and number 2 tank agent capacity is displayed on the right needle indicator. In the same manner, the agent level in tanks 3 through 8 can be read. If a tank is selected which is not in the given system (i.e., tank No. 6 in a two-tank system), the indicator needle will pin off scale, above the full mark.

3.3.5.11 Spray

The spray switch opens the end tank vent valves and the on-off main spray valve (3-inch butterfly) simultaneously, allowing the tanks to empty sequentially from the end tanks to the innermost tanks (both sides of the power module simultaneously). The

operator spray switch is in series with the pilot's spray switch so that both switches must be thrown to initiate spraying, but either the operator or pilot can terminate spraying. Two indicator lights next to the spray switch indicate if the pilot's or operator's spray switch is on.

3.3.5.12 Main Power

The main power switch supplies power to all system functions and is also a circuit breaker. All subcircuits are individually protected with circuit breakers, and an indicator light illuminates if any circuit breaker is activated to the OFF position. A hinged panel provides circuit breaker access.

3.3.5.13 Engine Controls

Engine controls include a start button, ignition switch (magneto ground), throttle, and choke. The choke and throttle levers are the push-pull type. Pulling the choke lever activates the choke; the throttle lever is pulled to decrease throttle and pushed in to increase throttle. Rotating the throttle lever clockwise will lock it in a given setting. The engine tachometer is located above the engine controls.

3.3.5.14 Engine Instruments

A twin needle indicator displays oil and engine head temperature. The hourmeter indicates elapsed operation time. The ammeter shows battery charging or discharging rate, and the oil pressure gage indicates engine oil pressure.

3.3.5.15 Panel Illumination Lights

Two flexible goose-neck panel lights are provided. These lights may be positioned as desired, include dimming devices, and can be adjusted to illuminate with either white light for day flying or red light for night flying.

3.3.6 Pilot Controls

Pilot controls are shown in Figure 14. Switches for spraying and dump are provided. A dump indicator illuminates if either the pilot or operator activates the function. Separate indicators for the pilot and operator are provided with the spray switch. The indicators are the press-to-test type and can be dimmed by rotating them. The pilot control box is connected to the power module control box with an electrical cable.

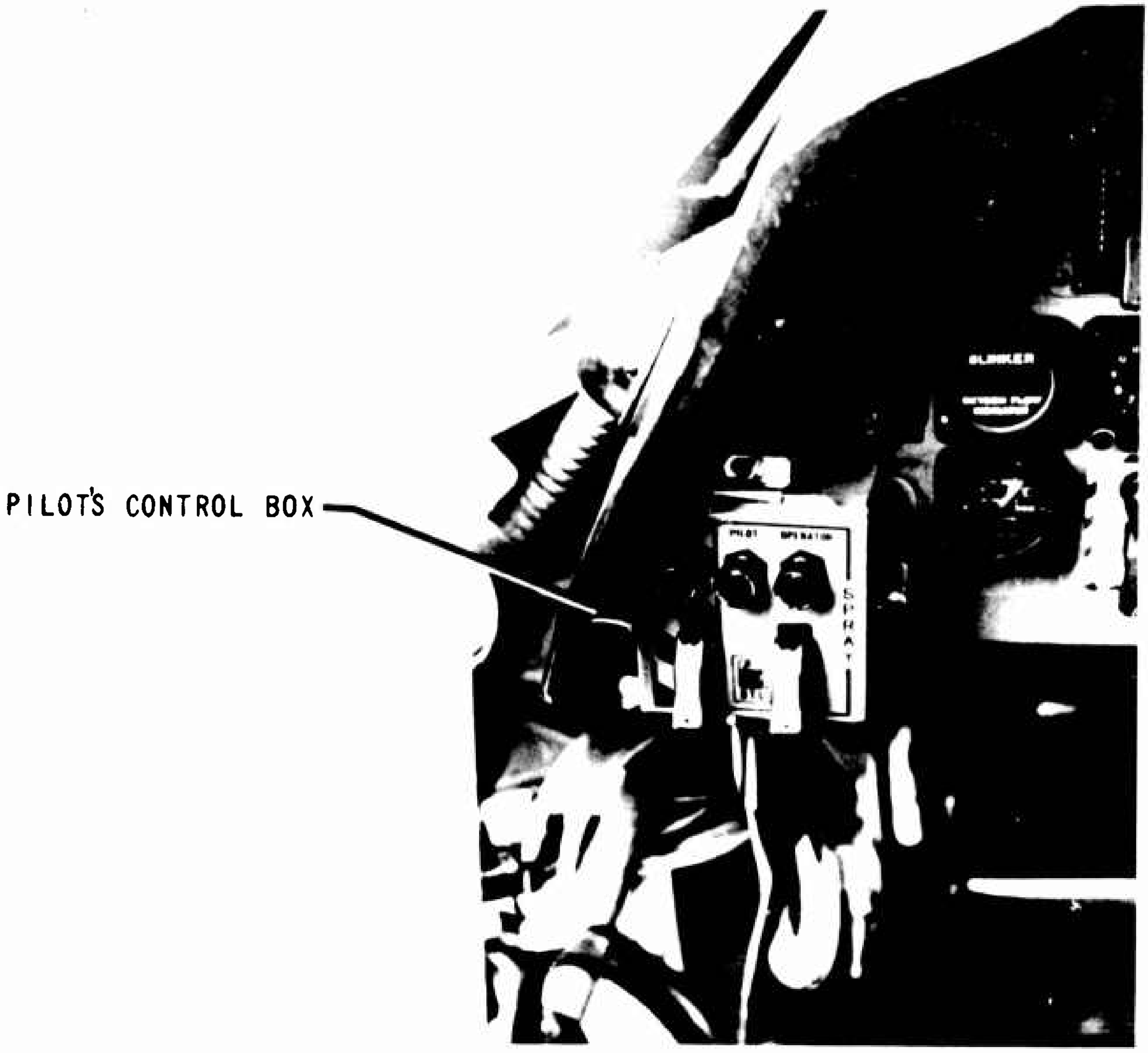


Figure 14. Pilot Controls

3.3.7 Electrical System

The main electrical power system consists of a 28-volt lead-acid aircraft battery, 50-ampere - 28.5-volt direct current generator powered by the PE90-7 engine, a carbon pile voltage regulator, and a reverse current relay. All secondary electrical systems are individually protected with circuit breakers.

A detailed explanation of the complete PWU-5/A MISS electrical system is presented in Appendix I of this report.

3.3.8 Emergency Dump System

The emergency dump system allows one-half the agent payload to be jettisoned overboard in less than 45 seconds. Each tank dump valve output is manifolded into a 10-inch-diameter duct which extends through an aft jump door. A single 10-inch dump line can handle up to four tanks; larger systems require two dump lines. The ducting is silicone-coated glass fiber, and fittings are stainless steel.

3.3.9 Tank Vent System

The complete MISS is sealed to prevent leakage of agent or agent vapors inside the aircraft. To accomplish this, the 2-inch-diameter tank vent hoses are manifolded into a 3-inch vent line and routed out a rear jump door. Each 3-inch line will handle four tanks; larger systems use two 3-inch vent lines. At the jump door the 3-inch vent line chute is positioned so the air-stream causes slight ram-air pressurization of the tanks, decreasing emergency dump time. All vent line ducting is silicone-coated glass fiber, and all fittings are stainless steel.

3.3.10 Internal/External Aircraft Plumbing

Agent suction lines are 4-inch-diameter flexible hose. The first MISS prototypes were supplied with a vinyl interim hose which should not be used with agents containing aromatic hydrocarbons. A stainless steel suction hose, which is compatible with all MISS agents, is specified with the system.

Recirculation and spray hoses are 3-inch-diameter cross-linked polyethylene-lined pressure hoses rated at 150 psig working pressure. All suction and pressure hoses are sanitary-type couplings.

Each aircraft used with the PWU-5/A MISS requires certain custom fittings to route the spray hose out the jump door to the wing booms. For complete information regarding internal/external plumbing for a specified aircraft, consult the PWU-5/A Modular Internal Spray System, Class II modification documentation for that aircraft.

3.3.11 Wing Boom System

The wing boom is a 2-inch stainless pipe streamlined with an aft fairing. Standard wing boom lengths are 8 feet and 4 feet. Variations of shape and length are required on certain aircraft. Sections are joined with flexible connectors, which allow angular movement but restrain axial movement and rotation.

Nozzle stations are located every two feet along the boom. Air-assisted diaphragm nozzle valves are used at each nozzle station to insure positive termination of spraying and prevent agent leakage through the nozzles when not spraying. A pneumatic line is located inside the boom fairing to supply air pressure to the nozzle shut-off valves.

Two size stainless steel nozzles are used: 1/2-inch high capacity nozzle rated at 7.5 gpm/nozzle at 10 psig to 23.7 gpm/nozzle at 100 psig; 1/4-inch low volume nozzle rated at 0.10 gpm/nozzle at 10 psig to 0.32 gpm/nozzle at 100 psig.

The booms are positioned underneath the wing and secured by struts and bonded mounting plates (bonded to the wing with aerospace adhesive).

3.3.12 Ground Support Equipment

Ground support equipment consists of:

- 50-foot, 2-inch-diameter suction/pressure hose
- 50-foot, 1-inch-diameter pressure hose
- 55-gallon drum suction probe assembly
- Tank washing probe
- Aircraft washing gun
- Adaptor fittings.

The 2-inch hose is used for suction filling or power draining. Attaching the drum suction probe assembly allows suction filling directly from 55-gallon drums. The 1-inch hose may be either connected directly to the power module or to the end of the 50-foot, 2-inch hose. The tank-washing probe includes a spherical spray head to wash down all internal tank surfaces when cleaning the system and is inserted through the tank fill cap opening. The aircraft washing gun has a variable spray which may be changed from a jet stream, cone spray, or shut off according to the gun's trigger position

SECTION IV

SYSTEM DEVELOPMENT

The following sections of this report present the development sequence of all PWU-5/A MISS hardware plus discussions of design criteria such as aircraft characteristics, chemical agents, and field operations.

4.1 AIRCRAFT CONSIDERATIONS

The PWU-5/A Modular Internal Spray System has been designed for use on a wide variety of cargo-type aircraft: C-46D, C-47D, C-54G, C-97G, C-118A, C-119G, C-121G, C-123K, C-130E, and C-131E.

Some of these aircraft date back to the late 1930's while others are modern-day sophisticated transports capable of carrying up to 45,000 pounds of cargo. This wide range of aircraft technology required extensive investigations to insure that suitable system/aircraft combinations resulted. The aircraft were divided into two groups: primary and secondary. The primary aircraft are the C-47D, C-54G, C-123K, and C-130E; other aircraft are termed as secondary. Some specific aircraft characteristics are shown in Table II.

The aircraft design considerations included aircraft compatibility, modifications required, installation and removal restraints, aircraft contamination, and spray performance. These subjects are discussed in the following sections to show the restraints placed on the design and to show how the design satisfies the restraints.

4.1.1 Aircraft Compatibility

To determine aircraft compatibility, several requirements were established. These requirements include:

- Using full aircraft payload capacity
- Attention to floor load limits
- Attention to center of gravity
- Fitment in allowable cargo space
- Attention to tie-down requirements
- Permitting access to emergency exits
- Permitting access to service points
- Withstanding airborne environments.

TABLE II. AIRCRAFT CHARACTERISTICS

		PRIMARY AIRCRAFT				SECONDARY AIRCRAFT					
		C-47D	C-54G	C-123K	C-130E	C-46D	C-97G	C-118A	C-119G	C-121G	C-131E
SPAN	FT	95.0	117.5	110.0	132.6	108.0	141.3	117.5	109.3	123.0	105.7
LENGTH	FT	64.5	93.9	75.8	97.7	76.3	110.3	106.9	86.5	113.6	79.1
HEIGHT	FT	16.9	27.5	34.1	38.0	21.8	38.3	28.4	26.3	24.8	27.8
ENGINES	...	2	4	2	4	2	4	4	2	4	2
MAXIMUM SPEED	KNOTS	221	290	200	326	260	310	329	242	295	295
CRUISE SPEED	KNOTS	142	167	141	291	129	200	229	146	212	170
OPERATING WEIGHT	LB	20,000	40,000	39,100	71,500	31,000	92,500	60,000	45,000	110,000	38,000
LOADED WEIGHT	LB	33,000	73,000	60,000	153,000	51,900	169,000	112,000	72,700	145,000	60,500
*MAX. PAYLOAD	LB	9,000	24,000	13,000	45,000	16,000	40,000	30,000	20,000	30,000	18,500
MAIN CARGO DOOR	...	SIDE	SIDE	REAR	REAR	SIDE	REAR	SIDE	REAR	SIDE	SIDE
DOOR HEIGHT	IN.	55-70	67	100	109	65.5-78.5	78	78	96	74	72
DOOR WIDTH	IN.	84	95	110	123	95.5	78	124	110	112	120
CARGO COMPARTMENT:											
HEIGHT	IN.	80	80	98	109	80	86	93	92	80	79
WIDTH	IN.	79	103	98-110	123	109	88-107	104	110	120	[illegible]
LENGTH	IN.	270	420	444	492	510	764	816	443	984	554
MAX. FLOOR LOAD	PSF	200	200	200	1080	185	200	200	200	300	300

*NOTE: PAYLOADS SHOWN ARE MAXIMUM FOR MISSIONS UTILIZING THE PWU-5/A MISS.

Since the PWU-5/A MISS must be capable of use on a wide variety of aircraft with cargo capacities varying from 9,000 pounds to 45,000 pounds, several trade-offs were made resulting in the final system. The system is able to satisfy the requirements of the large aircraft, and by rearranging the modules and connective plumbing and reducing the number of tank modules, the system is made compatible with other aircraft.

Parameters of the various aircraft/system combinations are shown in Table III. The weights and payload efficiencies do not include the weight of connective plumbing and booms. It is seen that the payload efficiency (without plumbing) is high, varying from 95 percent to 67 percent. For those aircraft which are payload limited, the PWU-5/A MISS utilizes nearly 100 percent of the aircraft payload capacity when the internal and external plumbing are included.

Since the system modules must be interchangeable, the most extreme environmental factors of the group of aircraft were considered. These factors, which were established as design goals, are presented in Table IV. Load factors were determined to meet the requirements of the applicable Air Force technical orders for normal and crash conditions. Aircraft attitude angles determined the amount of center of gravity control which must be provided by the PWU-5/A MISS. Altitude and temperature ranges were determined to aid in the design of system components. A design dynamic pressure was established for the determination of maximum air loads on external components.

Specific module layouts for the various aircraft are discussed below. Particular attention was given to satisfying floor loading, compartment loading, and center of gravity requirements while exploiting maximum possible payload capacities.

4.1.1.1 Primary Aircraft

- C-47D

The module layout for the C-47D is presented in Figure 15. Two tank modules and one power module are shown. The fuselage is divided into compartments along its length. Each compartment has a weight capacity independent of other compartments.

Center of gravity conditions were satisfied assuming a basic aircraft, crew, and fuel c.g. at the forward aircraft c.g. limit. The modules were then positioned such that the aircraft c.g. remained within limits. These c.g. requirements limited the load of the aft tank. The forward portion of the main cargo door is removed for routing of connective plumbing.

TABLE III. AIRCRAFT/SYSTEM PARAMETERS

TANK MODULE WEIGHT: 653 POUNDS EMPTY

POWER MODULE WEIGHT: 2,050 POUNDS

AIRCRAFT	NUMBER TANK MODULES	AGENT (1) CAPACITY (GAL.)	MODULAR (2) WEIGHT (POUNDS)	PAYLOAD (3) EFFICIENCY	LIMITING FACTOR
C-46D	4	996	12,982	0.81	COMPARTMENT LOAD
C-47D	2	466	7,250	0.81	CENTER OF GRAVITY
C-54G	4	1,925	20,738	0.86	LATERAL RESTRAINT
C-97G	8	3,494	36,450	0.91	PAYLOAD
C-118A	6	2,592	27,598	0.92	PAYLOAD
C-119G	4	1,724	19,050	0.95	PAYLOAD
C-121G	6	2,592	27,598	0.92	PAYLOAD
C-123K	2	992	11,712	0.90	PAYLOAD
C-130E	8	3,968	40,698	0.90	PAYLOAD
C-131E	4	932	12,450	0.67	COMPARTMENT LOAD

NOTES:

(1) SPECIFIC GRAVITY 1.0

(2) INCLUDING POWER MODULE, TANK MODULES. WITH S.G = 1.0 AGENT, EXCLUDING CONNECTIVE PLUMBING, WING BOOMS, ETC.

(3) RATIO OF MODULAR WEIGHT TO MAXIMUM AIRCRAFT PAYLOAD.

TABLE IV. ENVIRONMENTAL FACTORS

1)	LOAD FACTORS

	NORMAL	CRASH
FORWARD	3.0 g	8.0 g
AFT	3.0 g	1.5 g
UP	3.0 g	2.0 g
DOWN	4.5 g	4.5 g
SIDE	1.5 g	1.5 g

2)	AIRCRAFT ATTITUDE FOR C.G. CONTROL

PITCH $\pm$ 30°
ROLL $\pm$ 60°

3)	ALTITUDE

CRUISE: 0 FEET TO 20,000 FEET - MEAN SEA LEVEL
SPRAY: 0 FEET TO 10,000 FEET - MEAN SEA LEVEL

4)	DESIGN DYNAMIC PRESSURE

400 KTAS AT SEA LEVEL
q = 544 PSF

5)	TEMPERATURE

STORAGE (WITHOUT AGENT)	−65°F TO +165°F	
INSTALLED WITH AGENT	−65°F TO +140°F	(OUTSIDE)
	+20°F TO +140°F	(INSIDE)
SPRAYING	+40°F TO +140°F	

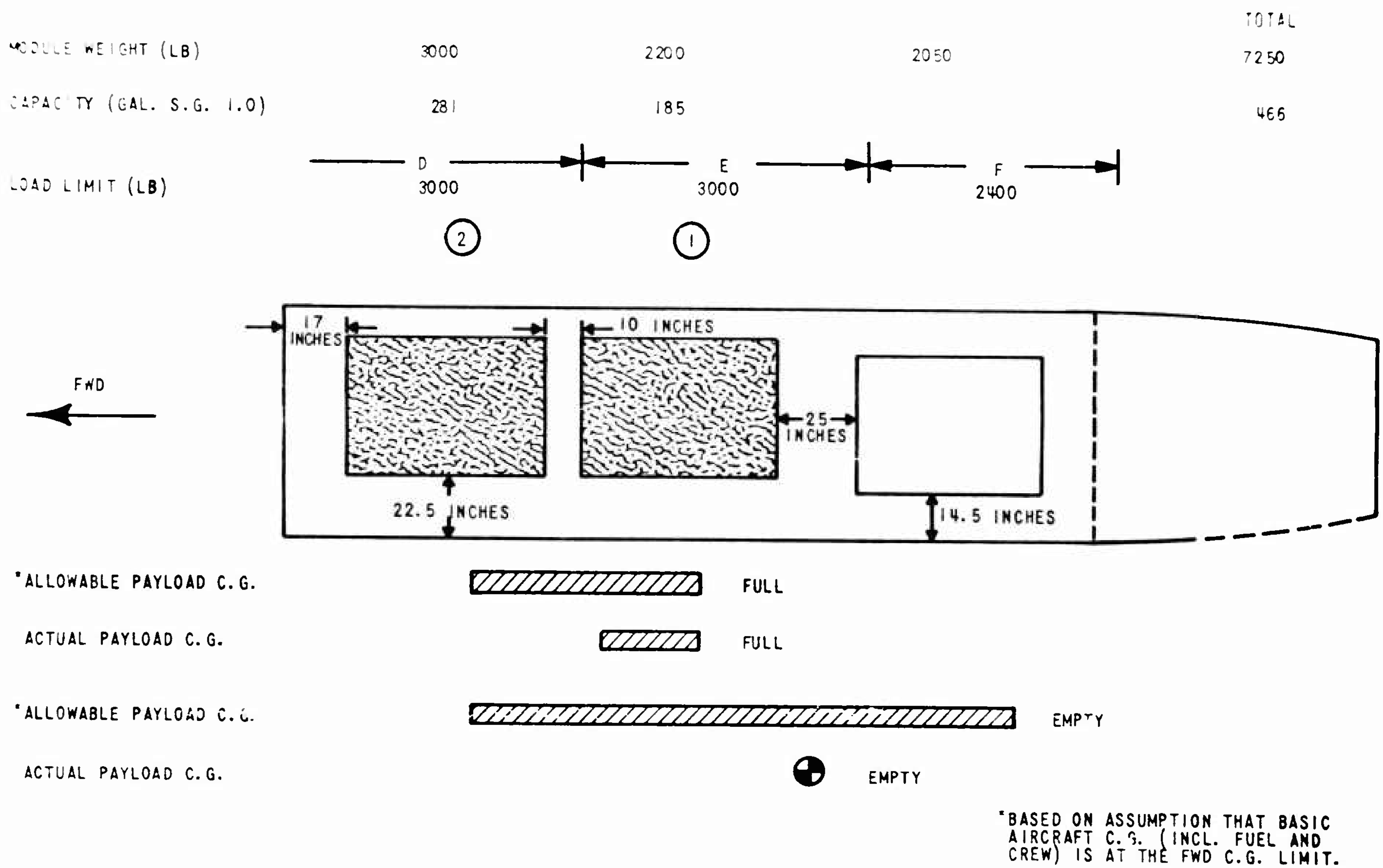


Figure 15. C-47D Floor Plan

Tie-down of modules should be in accordance with the cargo loading T.O.'s of the applicable C-47 model. Due to extreme variance of tie-down locations and strengths between C-47 models, no single tie-down procedure is applicable.

- C-54G

The 4-tank module layout proposed for the C-54G is presented in Figure 16. The versatility of the modules, necessary to maximize payload capabilities, may be seen in this layout. The modules are oriented crosswise in the cargo compartment in order to satisfy center-of-gravity requirements. The two end tanks will empty first, and the two center tanks will empty last. The forward portion of the aft cargo door will be removed to provide the opening for connective plumbing.

Due to restraint capability of the cargo tie-downs, the forward tank must be limited to a total weight of 4332 pounds. In addition, it is required to directly bolt the cradles to floor fittings and to use several tie-down brackets to maximize the available restraint. Table V presents the recommended tie-down scheme. The tie-down fitting number is composed of the compartment, the row (from left to right), the type fitting (primarily used for engine tie-down or general cargo), and the numerical position (from forward) of the fitting in the particular compartment row.

- C-123K

The module layout for the C-123K is presented in Figure 17. Two tank modules and a power module are used, and the small c.g. band requirements are satisfied by this arrangement as shown. The tanks empty simultaneously.

Cargo tie-down fittings are adequate, passageways are sufficient, and the forward bail-out chute is not obstructed. Floor and compartment loading requirements are satisfied. The two aft jump doors are removed to provide openings for connective plumbing. Tie-down details are presented in Table VI; fitting nomenclature is standard to the aircraft.

- C-130E

The module layout for the C-130E is presented in Figure 18. The full capacity eight-tank system is shown. The module layout satisfies c.g., floor loading, and compartment loading requirements, and the jump doors provide openings for connective plumbing.

Tie-down details are presented in Table VII. Fitting nomenclature is standard to the aircraft. For the prototype test system, a four-tank assembly was designed and fabricated.

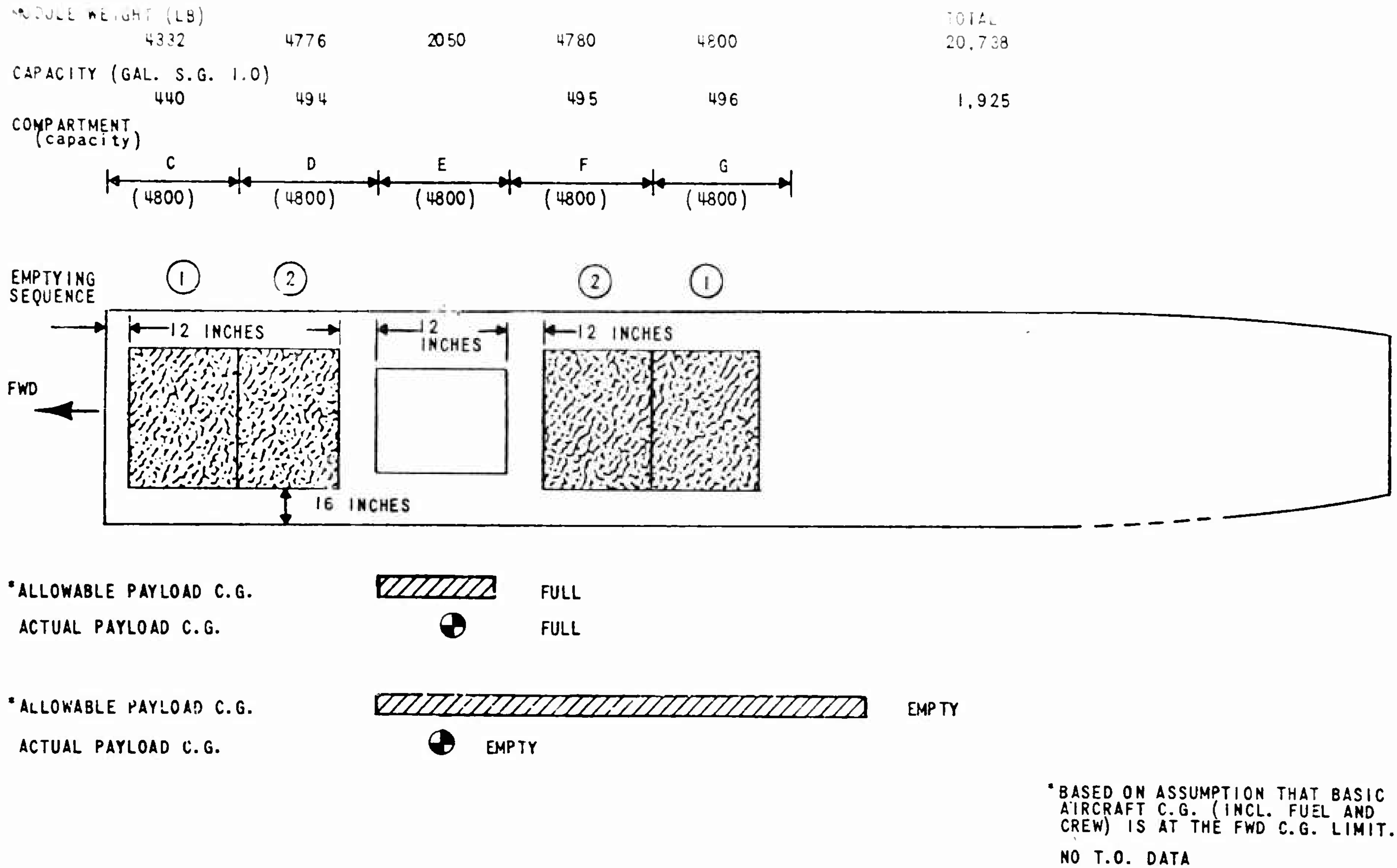


Figure 16. C-54G Floor Plan

TABLE V. C-54G TIE-DOWN DETAILS

MODULE	TIE-DOWN FITTING NO.	TIE-DOWN DEVICE QTY	TIE-DOWN DEVICE SIZE	ATTACHMENT POINT
1 (MOST AFT)	G-A-C-3	1	1250	LEFT AFT CORNER
	H-A-C-1			
	H-B-C-1			
	H-C-C-1			LEFT AFT CORNER
	H-D-C-1			RIGHT AFT CORNER
	H-E-C-1			RIGHT AFT CORNER
	G-F-C-3			RIGHT AFT CORNER
	H-F-C-1		1250	RIGHT AFT CORNER
	G-B-C-1		BOLT	THROUGH CRADLE
	G-B-E-1			
	G-B-C-2			
	G-B-E-2			
	G-B-C-3			
	G-C-C-1			
	G-C-C-2			
	G-C-C-3			
	G-D-C-1			
	G-D-E-1			
	G-D-C-2			
	G-D-E-2			
	G-D-C-3			
	G-E-C-1			
	G-E-E-1			
	G-E-C-2			
	G-E-E-2			
	G-E-C-3		BOLT	THROUGH CRADLE
2	F-A-C-1		1250	LEFT FWD CORNER
	F-A-C-2			LEFT FWD CORNER
	F-A-C-3			LEFT AFT CORNER
	G-A-C-1			LEFT AFT CORNER
	G-A-C-2			LEFT AFT CORNER
	F-B-C-1			RIGHT FWD CORNER
	F-C-C-1			RIGHT FWD CORNER
	F-D-C-1			LEFT FWD CORNER
	F-E-C-1			LEFT FWD CORNER
	F-F-C-1			RIGHT FWD CORNER
	F-F-C-2	1	1250	RIGHT FWD CORNER

TABLE V. (CONTINUED)

MODULE	TIE-DOWN FITTING NO.	TIE-DOWN DEVICE		ATTACHMENT POINT
		QTY	SIZE	
2 (CONTINUED)	F-F-C-3	1	1250	RIGHT AFT CORNER
	G-F-C-1			RIGHT AFT CORNER
	G-F-C-2		1250	RIGHT AFT CORNER
	F-B-E-1		BOLT	THROUGH CRADLE
	F-B-C-2			
	F-B-C 3			
	F-C-C-2			
	F-C-C-3			
	F-D-E-1			
	F-D-C-2			
	F-D-E-2			
	F-D-C-3			
	F-D-E-3			
	F-E-E-1			
	F-E-C-2			
	F-E-C-3		BOLT	THROUGH CRADLE
POWER MODULE	E-A-C-2		1250	LEFT FWD CORNER
	E-A-C-3			LEFT AFT CORNER
	E-F-C-2			RIGHT FWD CORNER
	E-F-C-3		1250	RIGHT AFT CORNER
	E-C-C-1		BOLT	THROUGH CRADLE
	E-C-C-2			
	E-C-C-3			
	E-D-C-1			
	E-D-E-1			
	E-D-C-2			
	E-D-E-2			
	E-D-C-3			
	E-D-E-3		BOLT	THROUGH CRADLE
3	D-A-C-2		1250	LEFT AFT CORNER
	D-A-C-3			LEFT AFT CORNER
	E-A-C-1			LEFT AFT CORNER
	E-B-C-1			LEFT AFT CORNER
	D-F-C-2			RIGHT AFT CORNER
	D-F-C-3			
	E-F-C-1			
	E-E-C-1		1250	RIGHT AFT CORNER
	D-B-C-1	1	BOLT	THROUGH CRADLE

TABLE V. (CONCLUDED)

MODULE	TIE-DOWN FITTING NO.	TIE-DOWN DEVICE QTY	TIE-DOWN DEVICE SIZE	ATTACHMENT POINT
3 (CONTINUED)	D-B-C-2	1	BOLT	THROUGH CRADLE
	D-B-E-1			
	D-B-C-3		BOLT	THROUGH CRADLE
	D-B-E-2		TIE DOWN BRACKET	AFT CRADLE
	D-C-C-1		BOLT	THROUGH CRADLE
	D-C-C-2			
	D-C-C-3			
	D-D-C-1			
	D-D-C-2			
	D-D-E-1			
	D-D-C-3		BOLT	THROUGH CRADLE
	D-D-E-2		TIE DOWN BRACKET	AFT CRADLE
	D-E-C-1		BOLT	THROUGH CRADLE
	D-E-C-2			
	D-E-E-1			
	D-E-C-3		BOLT	THROUGH CRADLE
	D-E-E-2		TIE DOWN BRACKET	AFT CRADLE
4 (MOST FWD)	C-A-C-1		"	LEFT SIDE
	C-A-C-2		TIE DOWN BRACKET	LEFT SIDE
	D-A-C-1		1250	LEFT AFT CORNER
	C-F-C-1		TIE DOWN BRACKET	RIGHT SIDE
	C-F-C-2		"	RIGHT SIDE
	D-F-C-1		1250	RIGHT AFT CORNER
	C-B-C-1		BOLT	THROUGH CRADLE
	C-B-E-1			
	C-B-C-2			
	C-C-C-1			
	C-C-C-2			
	C-D-C-1			
	C-D-E-1			
	C-D-C-2			
	C-E-C-1			
	C-E-E-1			
	C-E-C-2	1	BOLT	THROUGH CRADLE
IN ADDITION		4	TIE-DOWN BRACKET	INTERCONNECT MODULE NO. 1 TO NO.2 AND MODULE NO. 3 TO NO. 4

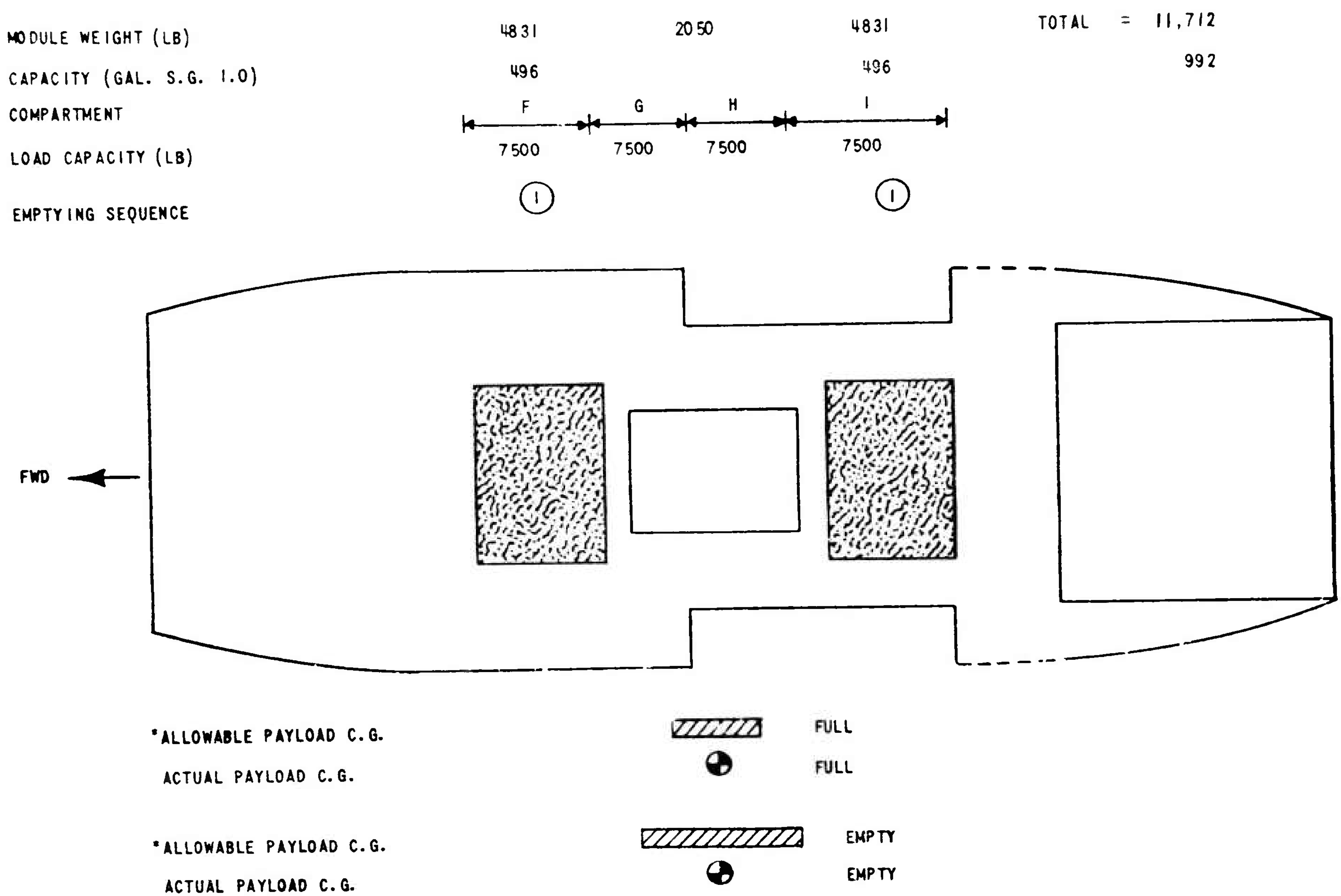


Figure 17. C-123K Floor Plan

TABLE VI. C-123 TIE-DOWN DETAILS

MODULE	TIE-DOWN FITTING NO.	ATTACHMENT POINT
FORWARD TANK	A- 8	LEFT AFT CORNER
	A- 9	LEFT FORWARD CORNER
	A-10	LEFT AFT CORNER
	E- 8	RIGHT AFT CORNER
	E- 9	RIGHT FORWARD CORNER
	E-10	RIGHT AFT CORNER
POWER MODULE	A-11	LEFT FORWARD CORNER
	A-12	LEFT AFT CORNER
	E-11	RIGHT FORWARD CORNER
	E-12	RIGHT AFT CORNER
AFT TANK	A-14	LEFT AFT CORNER
	A-16	LEFT FORWARD CORNER
	A-18	LEFT AFT CORNER
	E-14	RIGHT AFT CORNER
	E-16	RIGHT FORWARD CORNER
	E-18	RIGHT AFT CORNER

NOTES:
TIE-DOWN DEVICE:
QUANTITY = 1
SIZE = 10,000

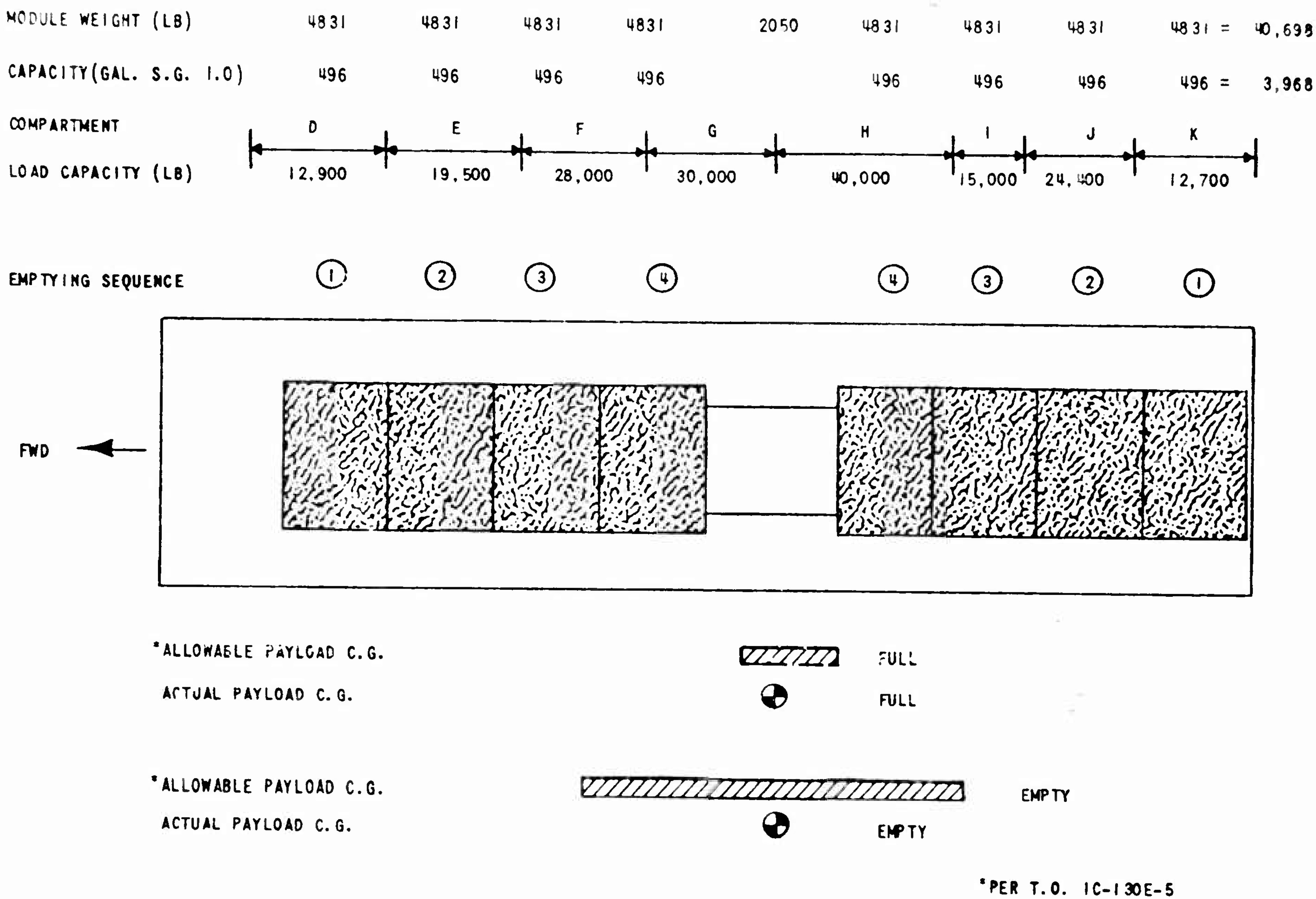


Figure 18. C-130E Floor Plan

TABLE VII. C-130E TIE-DOWN DETAILS

MODULE	TIE-DOWN FITTING NUMBER	ATTACHMENT POINT
8 (MOST FWD)	4A	LEFT AFT CORNER
	4G	RIGHT AFT CORNER
	5A	LEFT FORWARD CORNER
	5G	RIGHT FORWARD CORNER
	6B	LEFT AFT CORNER
	6F	RIGHT AFT CORNER
7	6A	LEFT AFT CORNER
	6G	RIGHT AFT CORNER
	8A	LEFT FORWARD CORNER
	8G	RIGHT FORWARD CORNER
	9B	LEFT AFT CORNER
	9F	RIGHT AFT CORNER
6	9A	LEFT AFT CORNER
	9G	RIGHT AFT CORNER
	10A	LEFT FORWARD CORNER
	10G	RIGHT FORWARD CORNER
	11B	LEFT AFT CORNER
	11F	LEFT RIGHT CORNER
5	11A	LEFT AFT CORNER
	11G	RIGHT AFT CORNER
	12A	LEFT FORWARD CORNER
	12G	RIGHT FORWARD CORNER
	13B	LEFT AFT CORNER
	13F	RIGHT AFT CORNER
POWER MODULE	14A	LEFT FORWARD CORNER
	14B	LEFT AFT CORNER
	14F	RIGHT AFT CORNER
	14G	RIGHT FORWARD CORNER
4	16A	LEFT AFT CORNER
	16G	RIGHT AFT CORNER
	18A	LEFT FORWARD CORNER
	18G	RIGHT FORWARD CORNER
	19B	LEFT AFT CORNER
	19F	RIGHT AFT CORNER
3	19A	LEFT AFT CORNER
	19G	RIGHT AFT CORNER
	20A	LEFT FORWARD CORNER
	20G	RIGHT FORWARD CORNER
	21B	LEFT AFT CORNER
	21F	RIGHT AFT CORNER
2	21A	LEFT AFT CORNER
	21G	RIGHT AFT CORNER
	22A	LEFT FORWARD CORNER
	22G	RIGHT FORWARD CORNER
	24B	LEFT AFT CORNER
	24F	RIGHT AFT CORNER
1 (MOST AFT)	23A	LEFT AFT CORNER
	23G	RIGHT AFT CORNER
	25A	LEFT FORWARD CORNER
	25B	LEFT FORWARD CORNER
	25F	RIGHT FORWARD CORNER
	25G	RIGHT FORWARD CORNER
NOTES: TIE-DOWN DEVICE - QUANTITY = 1	SIZE = 10,000	

4.1.1.2 Secondary Aircraft

The compatibility restraints of the secondary aircraft are satisfied in a similar manner as the primary aircraft. Figures 19 through 24 and Tables VIII through X show the module layouts and tie-down details where tie-down data was available.

4.1.2 Aircraft Modifications

One primary goal in designing the MISS was to allow the system to be rapidly installed while minimizing aircraft modification. Welding and metal-cutting operations were to be avoided. This philosophy was followed; major internal hardware is secured using standard tie-down devices. External hardware is attached to mounting plates which are bonded to the external aircraft surfaces.

Complete modification information for the C-47, C-123, and C-130 is contained in their respective Class II modification documents. Figures 25 and 26 show the MISS test kits as installed on the C-47 and C-130 aircraft. Figure 1 (Section III of this report) shows the C-123K installation.

4.1.2.1 Internal Modifications

The jump door openings were chosen as the location for the internal/external plumbing connection, the vent and dump outlets, battery and gas tank vents, and engine exhaust. This requires the jump doors to be removed for spraying but provides convenient routing without modifying the aircraft. The plumbing at the doors can be removed and doors closed for ferrying. Several alternate openings were considered. A hole could be conveniently cut in the fuselage to minimize pipe length requirements, but this is time-consuming and is a major metal-cutting operation. Removal of a window was considered, but it would not adequately serve as a route for the emergency dump line since the dump line must be below the tanks to allow gravity flow. Removing an emergency exit is fast; again, this does not present an attractive means of routing the dump line.

The pilot's control box location was determined for each aircraft during the system fit tests according to the pilot's preferences. Most pilot control box brackets can be either bonded or bolted in place. The C-123 box bracket is bonded, the C-130 bolted to the window frame, and the C-47 pop-riveted to the central control console.

The dump chute, vent chute, and exhaust chute, located at the jump door, are mounted to brackets which, in turn, are bonded to the aircraft interior. The bonding agent specified is silicone which can be easily removed when desired to restore the aircraft interior to its original non-modified condition. Another method

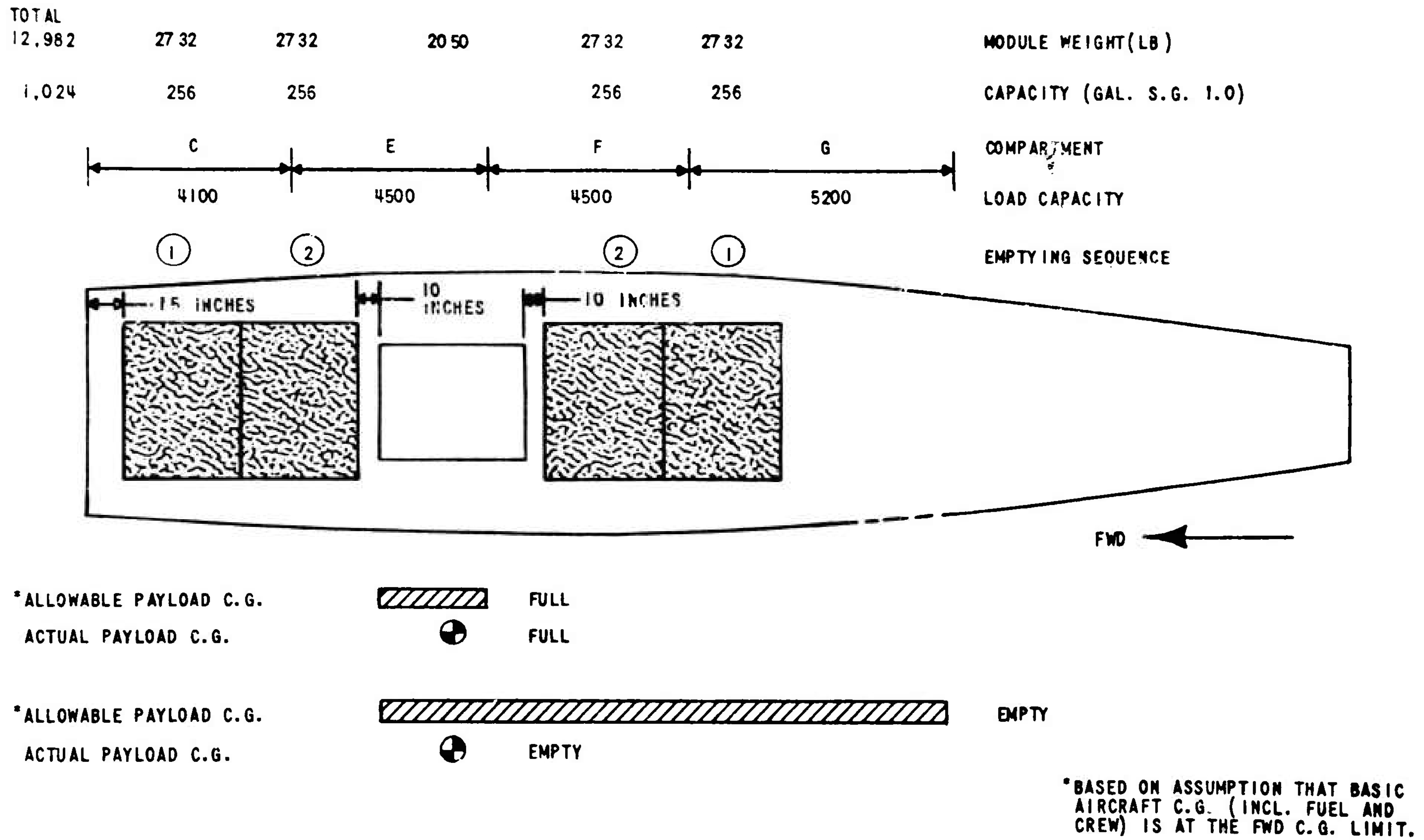


Figure 19. C-46D Floor Plan

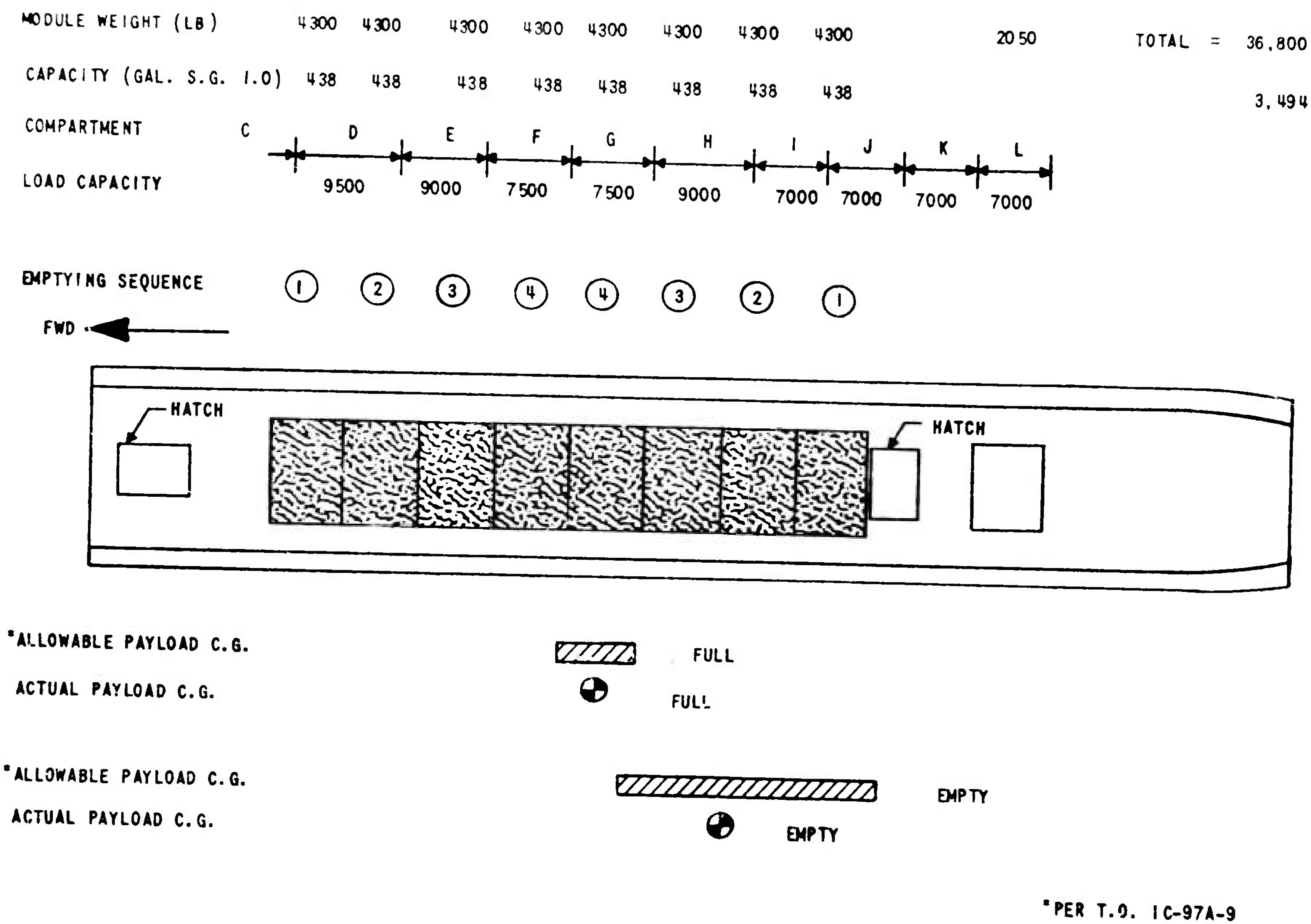


Figure 20. C-97G Floor Plan

TABLE VIII. C-97G TIE-DOWN DETAILS

MODULE	TIE-DOWN FITTING NO.	TIE-DOWN DEVICE QTY	TIE-DOWN DEVICE SIZE	ATTACHMENT POINT
POWER MODULE	L-41L	1	TIE-DOWN BRACKET	LEFT SIDE
	L-42R		TIE-DOWN BRACKET	RIGHT SIDE
	M-51L		10,000	LEFT AFT CORNER
	M-51R		10,000	RIGHT AFT CORNER
1 (AFT TANK)	I-41L		BOLT	THROUGH CRADLE
	J-41R		BOLT	THROUGH CRADLE
	L-71L		10,000	LEFT AFT CORNER
	L-71R		10,000	RIGHT AFT CORNER
	L-51L		10,000	LEFT FWD CORNER
	L-51R		10,000	RIGHT FWD CORNER
2	H-43L		BOLT	THROUGH CRADLE
	I-41R		BOLT	THROUGH CRADLE
	N-81L		25,000	FWD LEFT CORNER
	N-61R		25,000	FWD RIGHT CORNER
3	H-41L		BOLT	THROUGH CRADLE
	H-41R		BOLT	THROUGH CRADLE
4	G-41L		BOLT	THROUGH CRADLE
	G-41R		BOLT	THROUGH CRADLE
	K-81L		25,000	FWD LEFT CORNER
	K-81R		25,000	FWD RIGHT CORNER
5	F-41L		BOLT	THROUGH CRADLE
	F-41R		BOLT	THROUGH CRADLE
6	E-42L		BOLT	THROUGH CRADLE
	E-41R		BOLT	THROUGH CRADLE
	I-81L		25,000	LEFT FWD CORNER
	I-81R		25,000	RIGHT FWD CORNER
7	D-41L		BOLT	THROUGH CRADLE
	D-41R		BOLT	THROUGH CRADLE
8 (FWD TANK)	C-42L		BOLT	THROUGH CRADLE
	D-41R		BOLT	THROUGH CRADLE
	G-81L		25,000	FWD LEFT CORNER
	G-81R	1	25,000	FWD RIGHT CORNER
IN ADDITION		2	BRACKET	CONNECT MODULE 1 AND 2
		2	BRACKET	CONNECT MODULE 2 AND 3
		2	BRACKET	CONNECT MODULE 4 AND 5
		2	BRACKET	CONNECT MODULE 6 AND 7

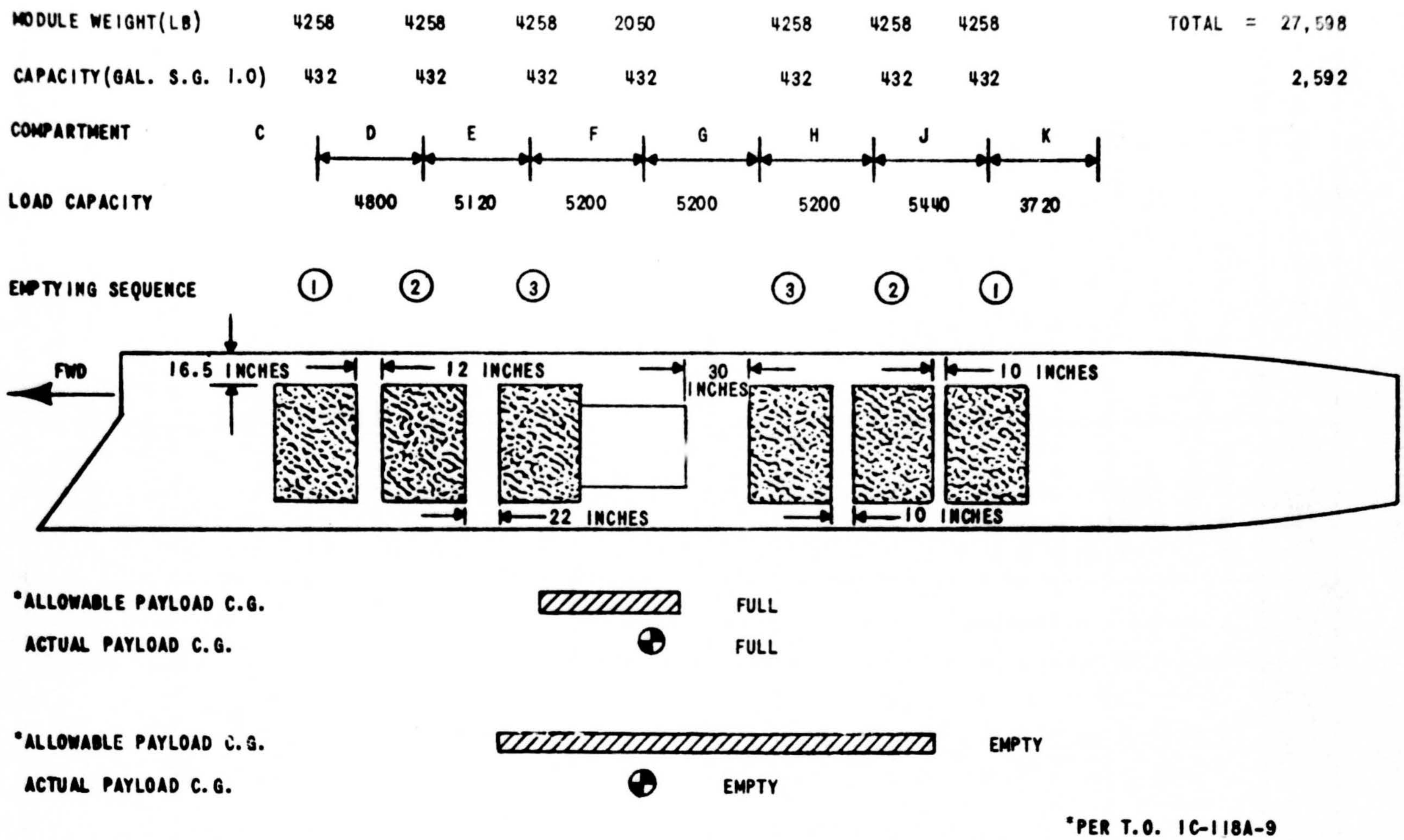


Figure 21. C-118A Floor Plan

TABLE IX. C-118A TIE-DOWN DETAILS

MODULE	TIE-DOWN FITTING NO.	TIE-DOWN DEVICE		ATTACHMENT POINT
		QTY	SIZE	
1 (AFT TANK)	B-29	1	5000	LEFT AFT CORNER
	B-30			
	B-31			
	B-32			
	C-29			
	C-30			
	C-31			
	C-32			
	A-24			
	A-33			LEFT AFT CORNER
	D-29			RIGHT AFT CORNER
	D-30			
	D-31			
	D-32			
	E-29			
	E-30			
	E-31			
	E-32			
	F-24			
	F-33			RIGHT AFT CORNER
2	A-19			LEFT FWD CORNER
	A-23			LEFT FWD CORNER
	A-25			LEFT FWD CORNER
	A-26			LEFT AFT CORNER
	F-19			RIGHT FWD CORNER
	F-23			RIGHT FWD CORNER
	F-25			RIGHT FWD CORNER
	F-26			RIGHT AFT CORNER
3	A-18			LEFT AFT CORNER
	A-20			LEFT FWD CORNER
	A-21			LEFT FWD CORNER
	A-22			LEFT FWD CORNER
	F-18			RIGHT AFT CORNER
	F-20			RIGHT FWD CORNER
	F-21			RIGHT FWD CORNER
	F-22			RIGHT FWD CORNER
4	A-14			LEFT FWD CORNER
	A-15			LEFT FWD CORNER
	A-16			LEFT AFT CORNER
	F-14			RIGHT FWD CORNER
	F-15			RIGHT FWD CORNER
	F-16		5000	RIGHT AFT CORNER
	B-16		10,000	LEFT AFT CORNER
	B-18		10,000	LEFT AFT CORNER
	D-16		10,000	RIGHT AFT CORNER
	D-18	1	10,000	RIGHT AFT CORNER

TABLE IX. (CONCLUDED)

MODULE	TIE-DOWN FITTING NO.	TIE-DOWN DEVICE QTY	TIE-DOWN DEVICE SIZE	ATTACHMENT POINT
5	A-10	1	5000	LEFT FWD CORNER
	A-11			
	A-12			LEFT FWD CORNER
	A-13			LEFT AFT CORNER
	F-10			RIGHT FWD CORNER
	F-11			RIGHT FWD CORNER
	F-12			RIGHT FWD CORNER
	F-13			RIGHT AFT CORNER
6	A-4			LEFT FWD CORNER
	A-7			
	A-8			
	A-9			
	B-4			
	C-4			LEFT FWD CORNER
	F-4			RIGHT FWD CORNER
	F-7			
	F-8			
	F-9			
	E-4			
	D-4			RIGHT FWD CORNER
POWER MODULE	B-15			LEFT FWD CORNER
	B-17			LEFT FWD CORNER
	E-15			RIGHT FWD CORNER
	E-17			RIGHT FWD CORNER
	B-16			LEFT AFT CORNER
	B-18			LEFT AFT CORNER
	E-16			RIGHT AFT CORNER
	E-18	1	5000	RIGHT AFT CORNER
IN ADDITION		2	BRACKET	CONNECT MODULE NO. 1 TO NO. 2
		2	BRACKET	CONNECT MODULE NO. 2 TO NO. 3
		2	BRACKET	CONNECT MODULE NO. 4 TO NO. 5
		2	BRACKET	CONNECT MODULE NO. 5 TO NO. 6

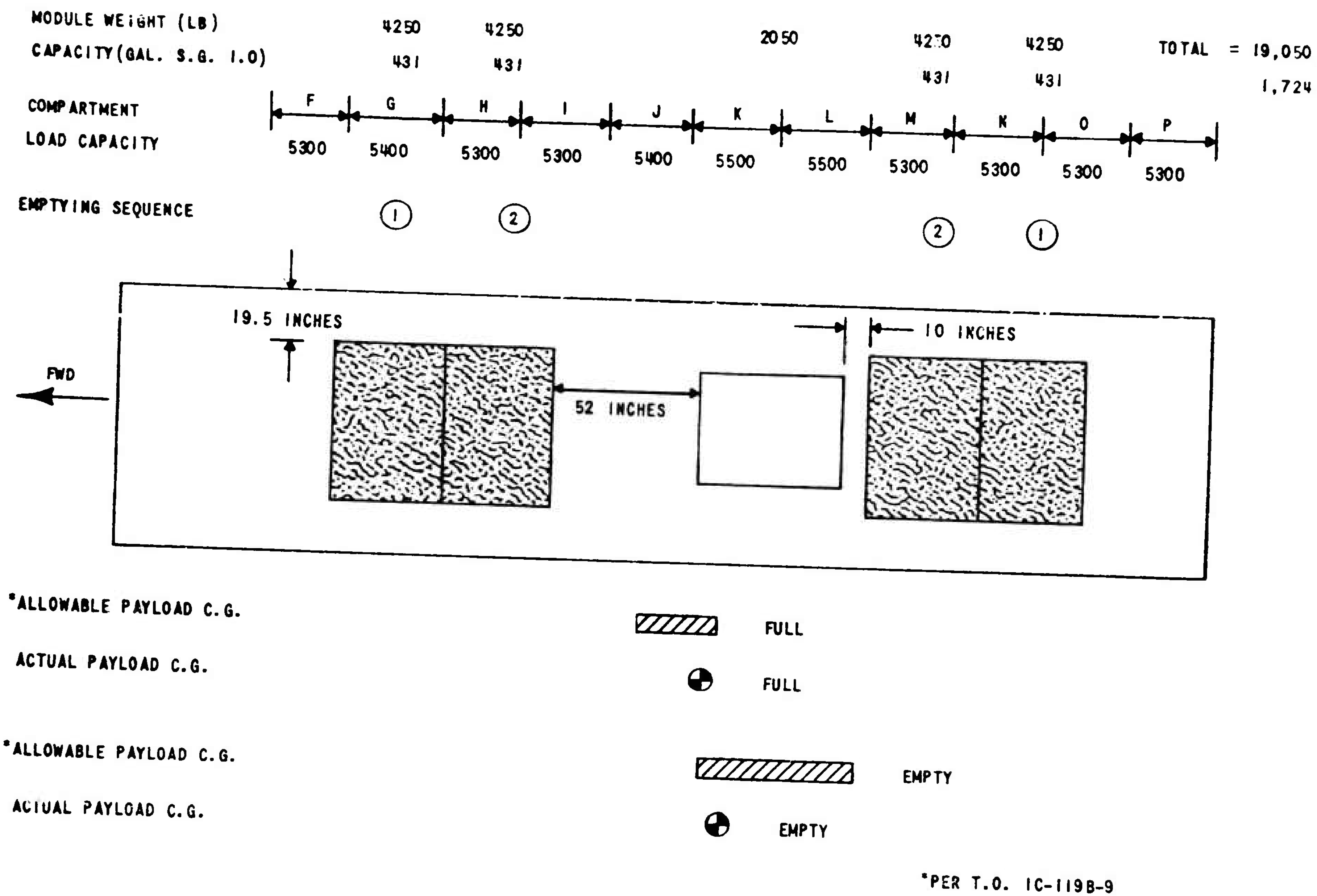


Figure 22. C-119G Floor Plan

TABLE X. C-119G TIE-DOWN DETAILS

MODULE	TIE-DOWN FITTING NO.	ATTACHMENT POINT
4	2	LEFT FORWARD CORNER
	5	LEFT FORWARD CORNER
	7	LEFT AFT CORNER
	65	RIGHT FORWARD CORNER
	68	RIGHT FORWARD CORNER
	70	RIGHT AFT CORNER
3	3	LEFT FORWARD CORNER
	6	LEFT FORWARD CORNER
	8	LEFT AFT CORNER
	24	LEFT AFT CORNER
	57	RIGHT AFT CORNER
	66	RIGHT FORWARD CORNER
	69	RIGHT FORWARD CORNER
	71	RIGHT AFT CORNER
POWER MODULE	10	LEFT FORWARD CORNER
	23	LEFT AFT CORNER
	56	RIGHT AFT CORNER
	73	RIGHT FORWARD CORNER
2	9	LEFT FORWARD CORNER
	12	LEFT FORWARD CORNER
	13	LEFT FORWARD CORNER
	72	RIGHT FORWARD CORNER
	75	RIGHT FORWARD CORNER
	76	RIGHT FORWARD CORNER
1	11	LEFT FORWARD CORNER
	14	LEFT FORWARD CORNER
	15	LEFT AFT CORNER
	30	RIGHT AFT CORNER
	63	LEFT AFT CORNER
	74	RIGHT FORWARD CORNER
	77	RIGHT FORWARD CORNER
	78	RIGHT AFT CORNER

NOTES:

TIE-DOWN DEVICE: QUANTITY = 1
SIZE = 10,000

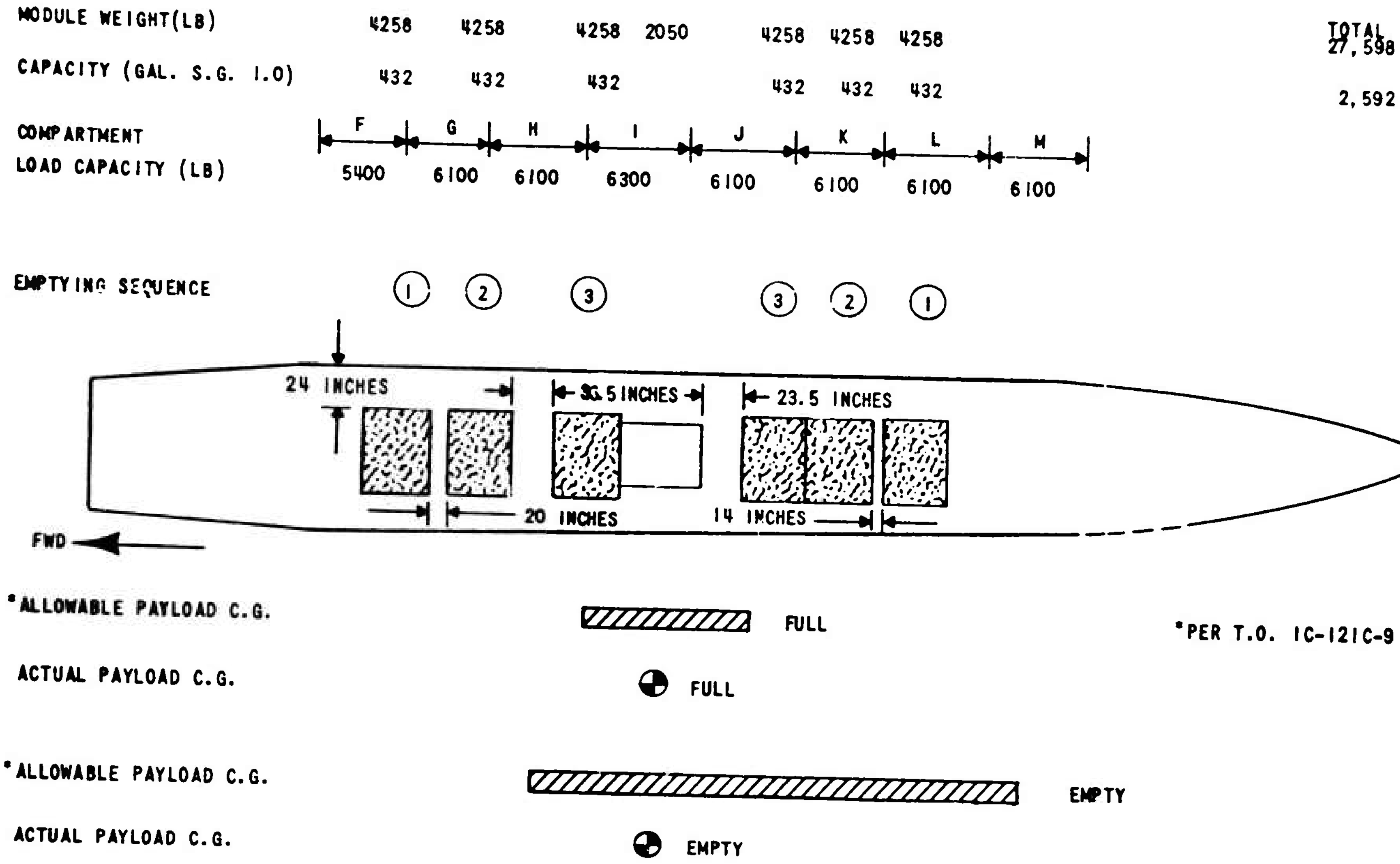


Figure 23. C-121G Floor Plan

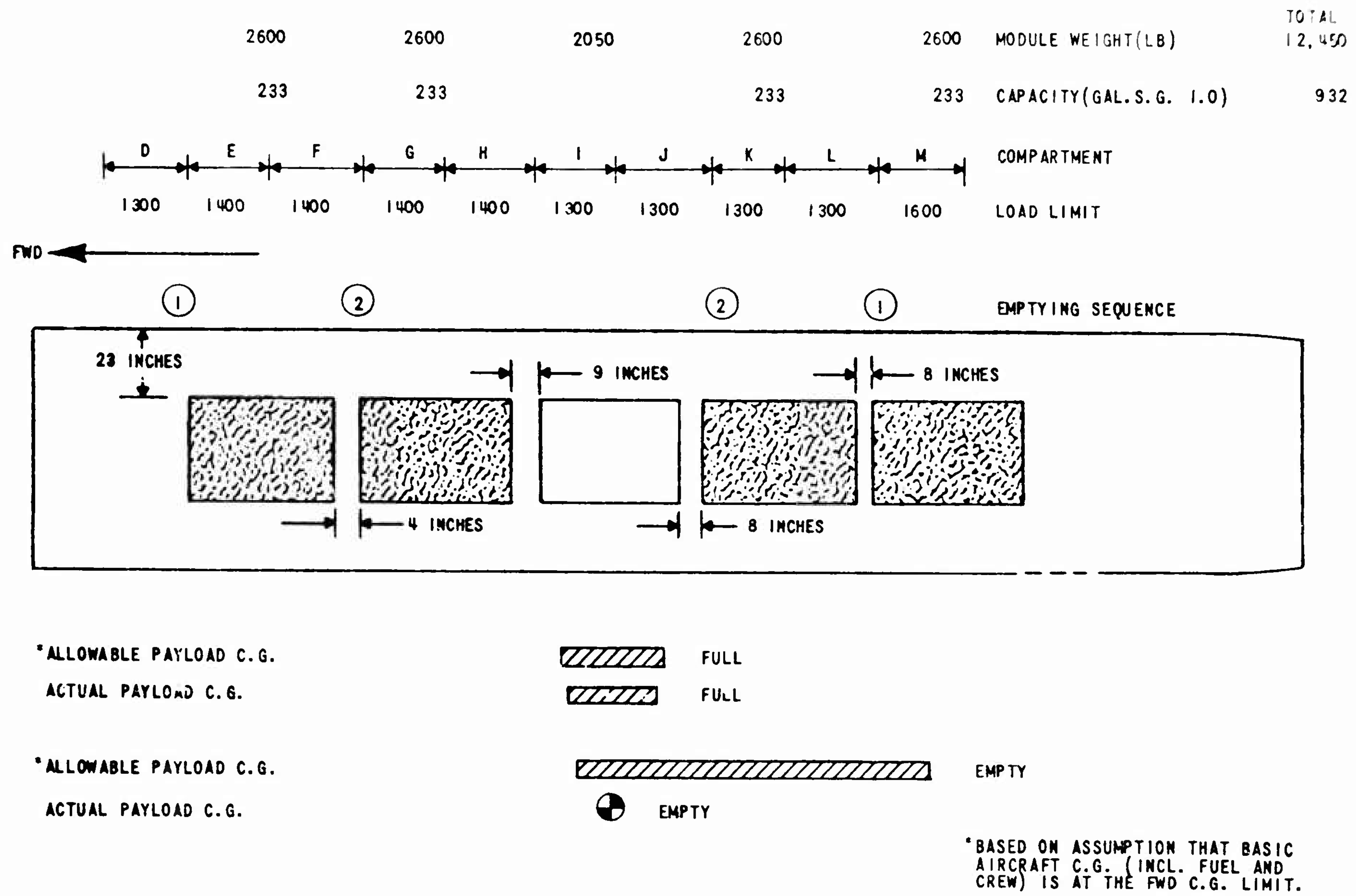


Figure 24. C-131E Floor Plan

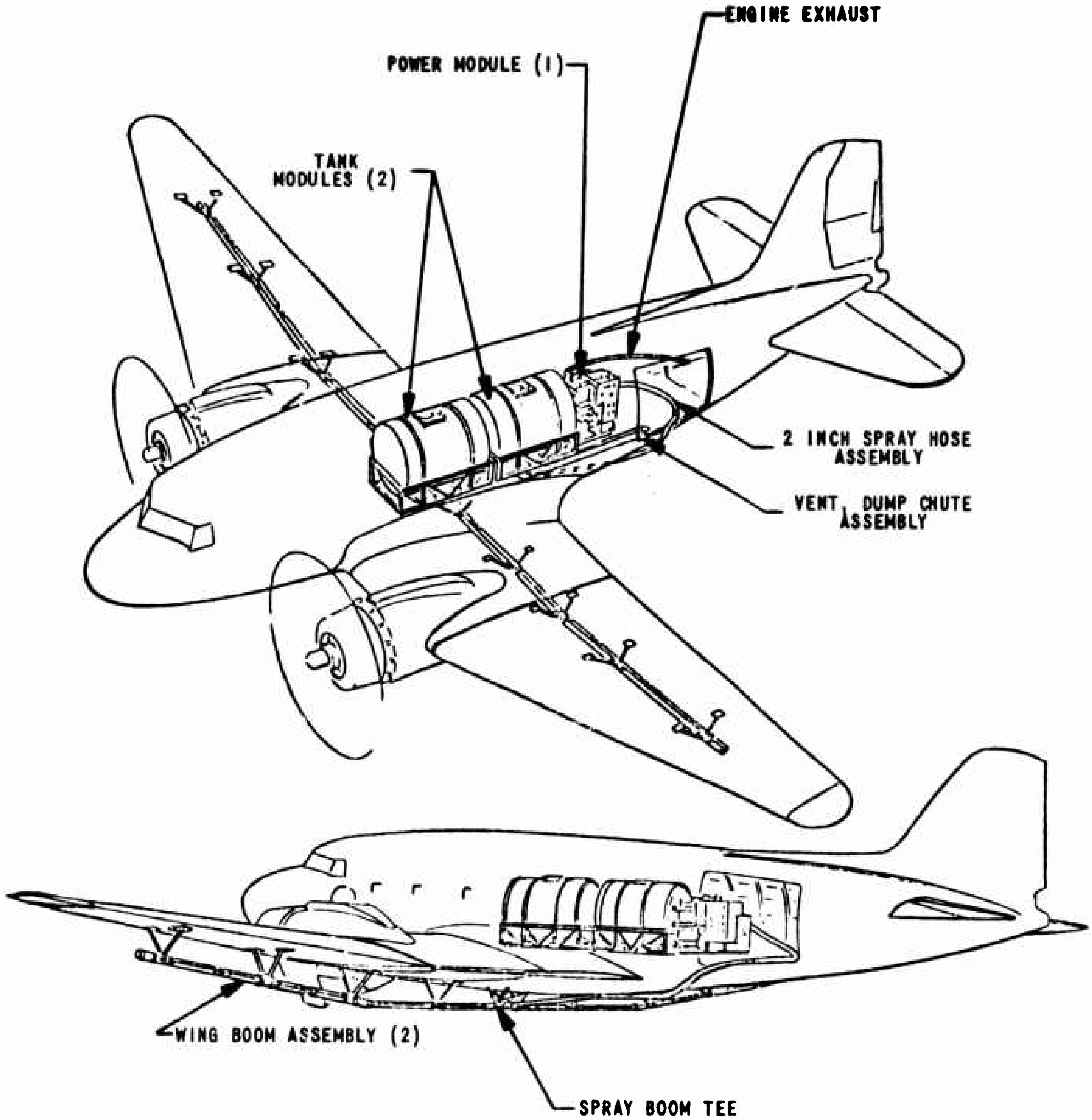
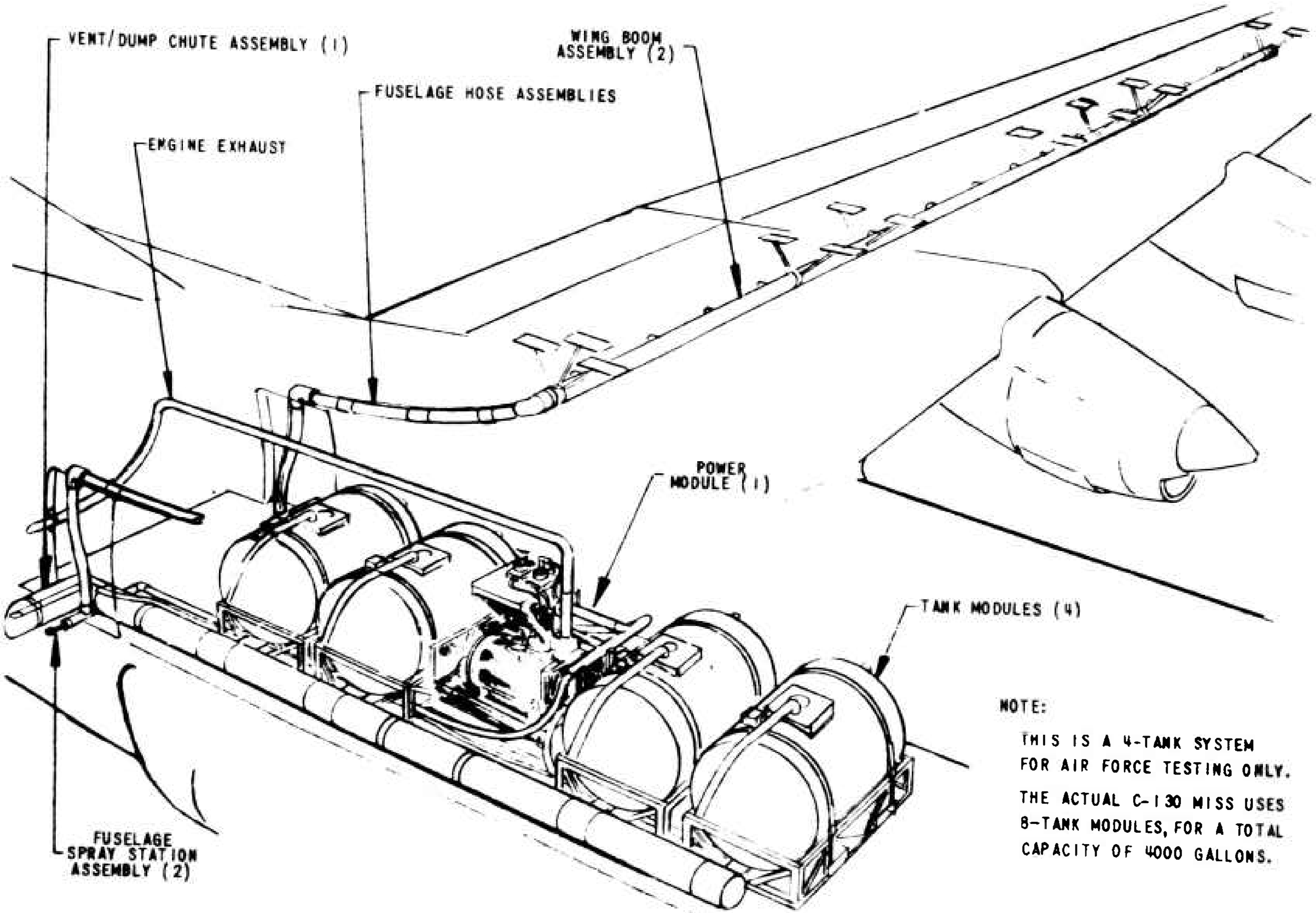


Figure 25. C-47 Modular Internal Spray System
Kit No. 4374132



NOTE:

THIS IS A 4-TANK SYSTEM FOR AIR FORCE TESTING ONLY.

THE ACTUAL C-130 MISS USES 8-TANK MODULES, FOR A TOTAL CAPACITY OF 4000 GALLONS.

Figure 26. C-130 Modular Internal Spray System Kit No. 4374236

considered was bolting the hardware to existing tie-down points, but this would require special brackets for each aircraft and would reduce the modularity of the PWU-5/A MISS.

4.1.2.2 External Modifications

The only modifications required to the exterior of the aircraft are those necessary to attach external plumbing, consisting of high-pressure hose along the fuselage and wing booms located approximately 12 inches under the wings.

Several methods of attachment were considered:

- Drilling and riveting
- Projection welding studs to the aircraft surface
- Bonding mounting plates.

Drilling and riveting would mean permanent aircraft modification, require highly trained modification personnel, would mean metal-cutting advised against by the Air Force, and could not be performed on wet wing aircraft. Therefore, this method of attachment was eliminated.

Projection welding studs to existing aircraft rivets or thick skin appeared to be a satisfactory solution, since it could be ground flush during demodification to restore the aircraft to its original condition. This method was rejected, however, after several tests proved that the rivet alloys were not compatible with stud welding since micro-cracks formed in the weld zone which would be vulnerable to fatigue propagation and subsequent weld failure.

As a result, bonding was selected as the best attachment method. To aid in the selection of a bonding agent, optimum requirements were established:

- Require little or no quality control
- Bond to an aluminum surface without special surface preparation other than solvent washing and priming
- Require no pressure or heat for curing
- Flexible (not subject to impact or fatigue)
- Viscous (allow adapter plates to be held in place without fixtures while the bonding agent cures)
- Resistant to temperature (-65 to +165°F), weather, aromatics, aliphatics
- Not critical to film thickness

- 40-psi tensile strength minimum with good peel

- Readily removed, if desired, to allow 100 percent aircraft demodification.

Using the above criterion, Dow Corning 93-046 two-part silicone adhesive was selected. Using this adhesive, several laboratory tests were run to determine adhesive tensile and shear ultimate strengths as a function of surface preparation and bonding agent thickness. The best results were obtained by preparing the aluminum test samples as follows:

1. Remove all paint using commercial paint stripper or wire brush.

2. Abrade surface with Scotch Brite pad using Scotch 3911 degreasing primer.

3. Allow primer to dry and dust off powder.

4. Reapply 3911 (do not abrade with Scotch Brite), allow to dry, and dust off powder.

5. Prime all surfaces with Dow Corning 1200 primer and allow to dry.

6. Apply DC 93-046 adhesive, making sure all aluminum surfaces are wetted.

7. Press samples together (hand pressure) and allow adhesive to cure.

Dow Corning recommends 24 hours for cure and 7 days for ultimate strength. Using the above procedure to prepare the aluminum samples, the following tensile and shear ultimate loads were obtained:

Type of Test	93-046 Thickness (in.)	Ultimate Load (psi)	Type of Failure
Tensile	0.010	496	Cohesive
Tensile	0.050	410	Cohesive
Tensile	0.100	328	Cohesive
Lap Shear	0.010	212	Cohesive
Lap Shear	0.050	262	Cohesive
Lap Shear	0.100	229	Cohesive

These results were obtained using the adhesive as it would be used in the field, without degassing the adhesive prior to bonding.

As explained in the C-123 Class II modification documentation, the worst case tensile load on the bonding agent (for the C-123K system) is 8.72 psi, and the worst case shear load is 3.33 psi. Therefore, the DC 93-046 bonding agent has a safety factor of over 30 based on ultimate strength.

An additional test was performed using two MISS wing boom mounting plates (Figure 27). These mounting plates were bonded together with outdated DC 93-046 adhesive by following the prescribed surface preparation and bonding procedure. After allowing the adhesive to fully cure, these plates were pulled in tension to failure. Figure 28 shows the results of this test. As can be seen, the plates held 10,000 pounds for over 20 seconds before yielding (tearing), and still supported 7600 pounds after yielding at 10,000 pounds to 7600 pounds. The maximum C-123K mounting plate tensile load is 258 pounds.

Since the exposed edges of the DC 93-046 adhesive could be wetted by fuel or spray agent in the actual MISS application, Dow Corning 94-003 Dispersing Coating was specified to coat all exposed silicone adhesive. This suspension coating is fluorosilicone which is resistant to fuels and agents, whereas the DC 93-046 adhesive could be degraded slightly by exposure to these agents.

The entire method of bonding was reviewed by personnel at Wright-Patterson Air Force Base who stated that polymer reversion would occur inside the silicone bonding agent whenever the bonding agent width exceeded 2 inches. Although there was no data available to prove this theory, several vented mounting plates were designed to provide a maximum bonding agent width of 2 inches, as shown in Figures 29 through 32. Of these special designs, Wright-Patterson Air Force Base personnel chose Design No. 2, Picture Frame with Gussets. Several of these plates were submitted to WPAFB for testing. For many of these tests, the bonded mounting plates were soaked in jet fuel, and subsequent tension tests revealed that the DC 94-003 dispersion coating did not protect the silicone bonding agent, and the silicone was badly degraded. After discussion with Dow Corning personnel, DTL suggested the use of DC 94-002 fluorosilicone sealant as a protection for the 93-046, since it could be applied thicker. Wright-Patterson Air Force Base personnel stated that even if the edges of the silicone bonding agent could be adequately protected, the bonding agent could be degraded by fuel leaks at rivets under the bonding agent when the MISS was installed on wet-wing aircraft. Because of this leaking rivet problem, Wright-Patterson Air Force Base personnel stated that silicone bonding agent could not be used to attach the wing booms on the MISS. Subsequently, Wright-Patterson Air Force Base personnel specified certain epoxies which could be used. DTL then designed a mounting plate with removable hanger specifically for use with epoxy bonding agents.

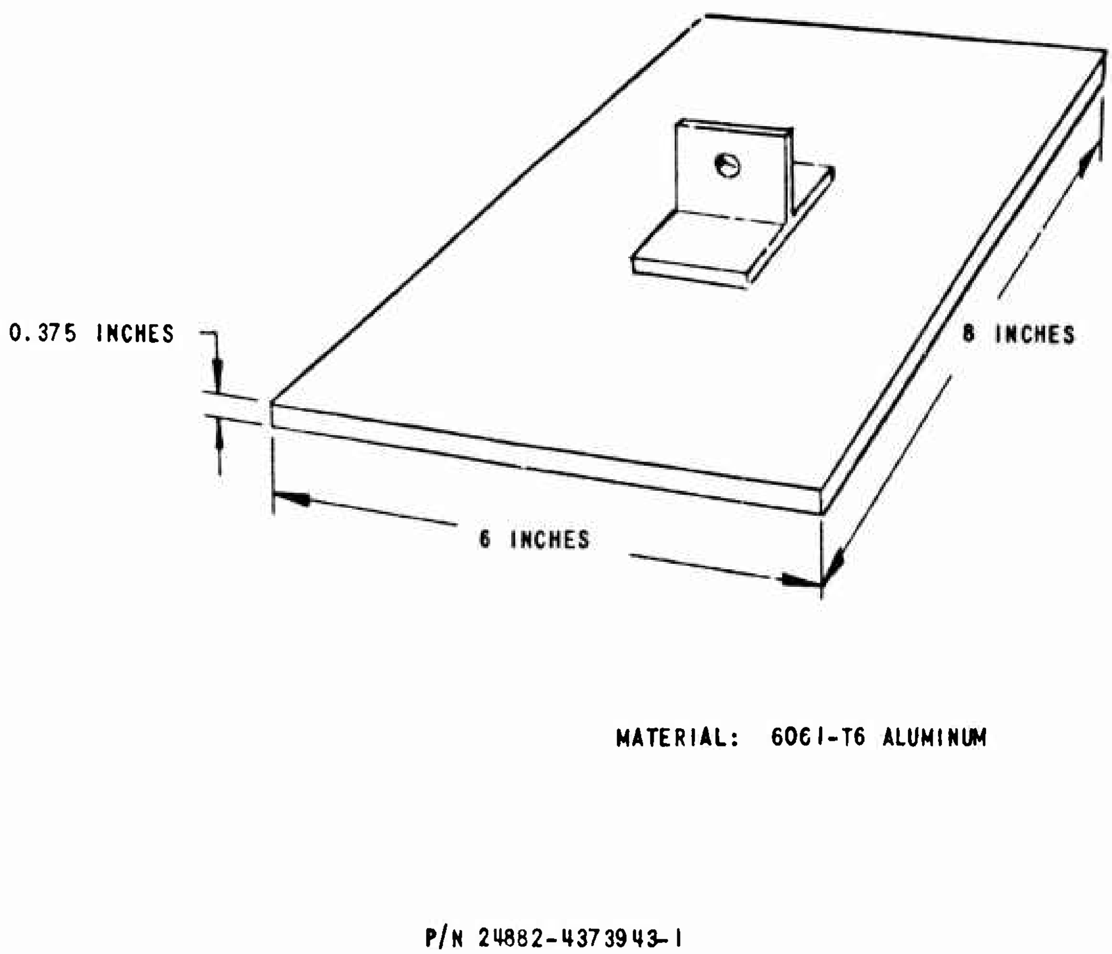


Figure 27. Mounting Plate (First Design)

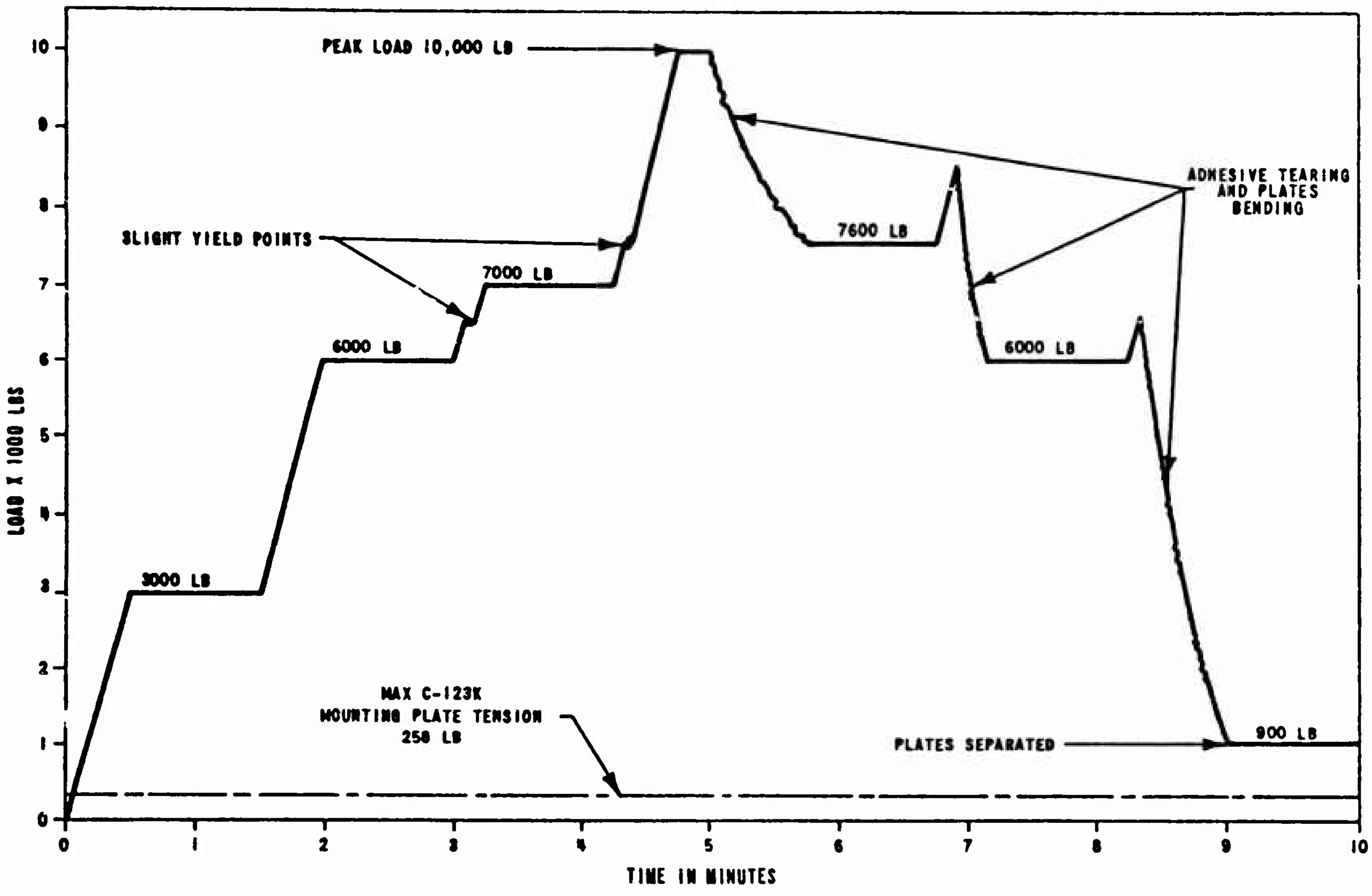


Figure 28. Bonded Mounting Plate Load-Time History

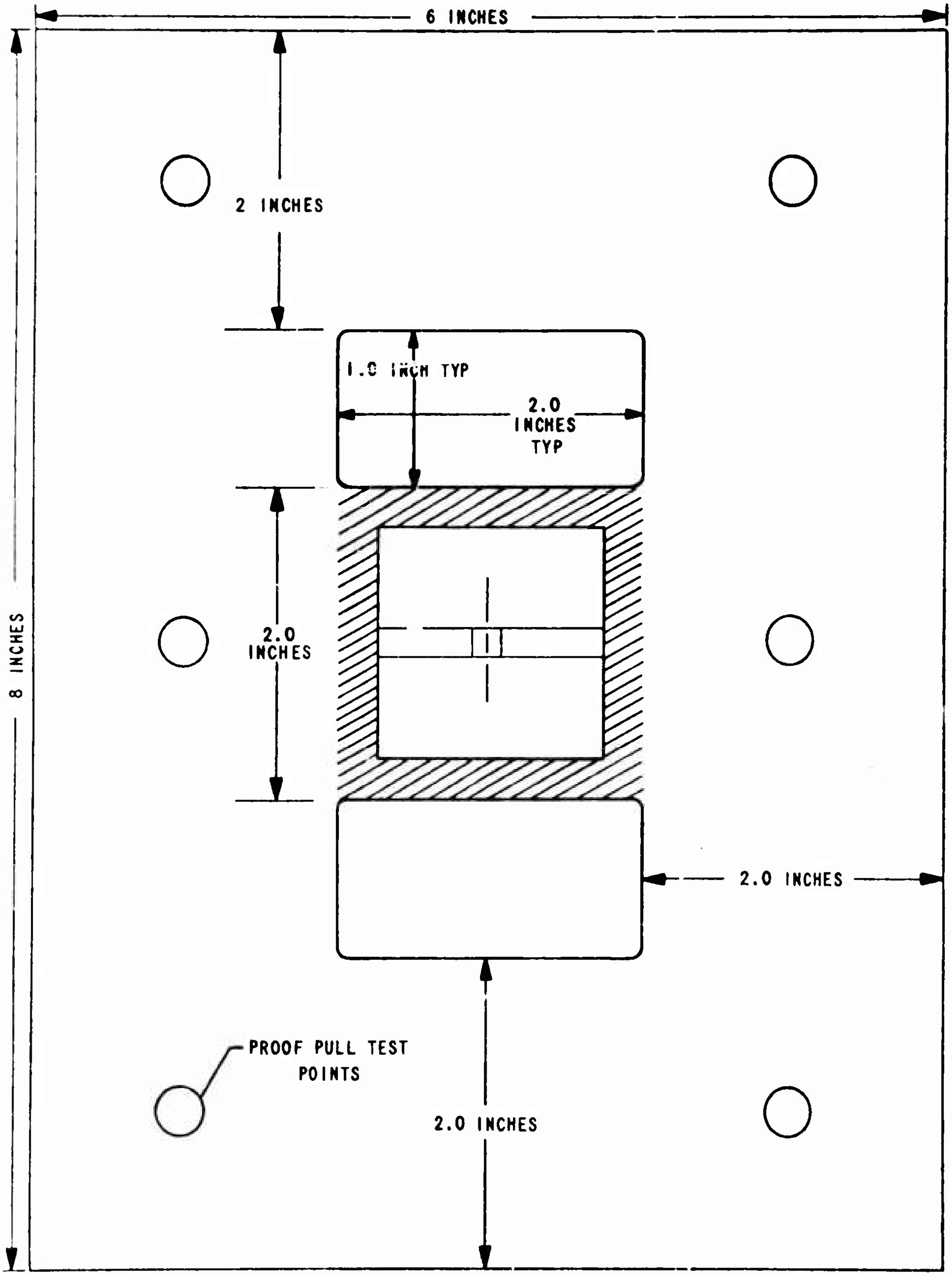


Figure 29. Modified Mounting Plate Design No. 1, Picture Frame

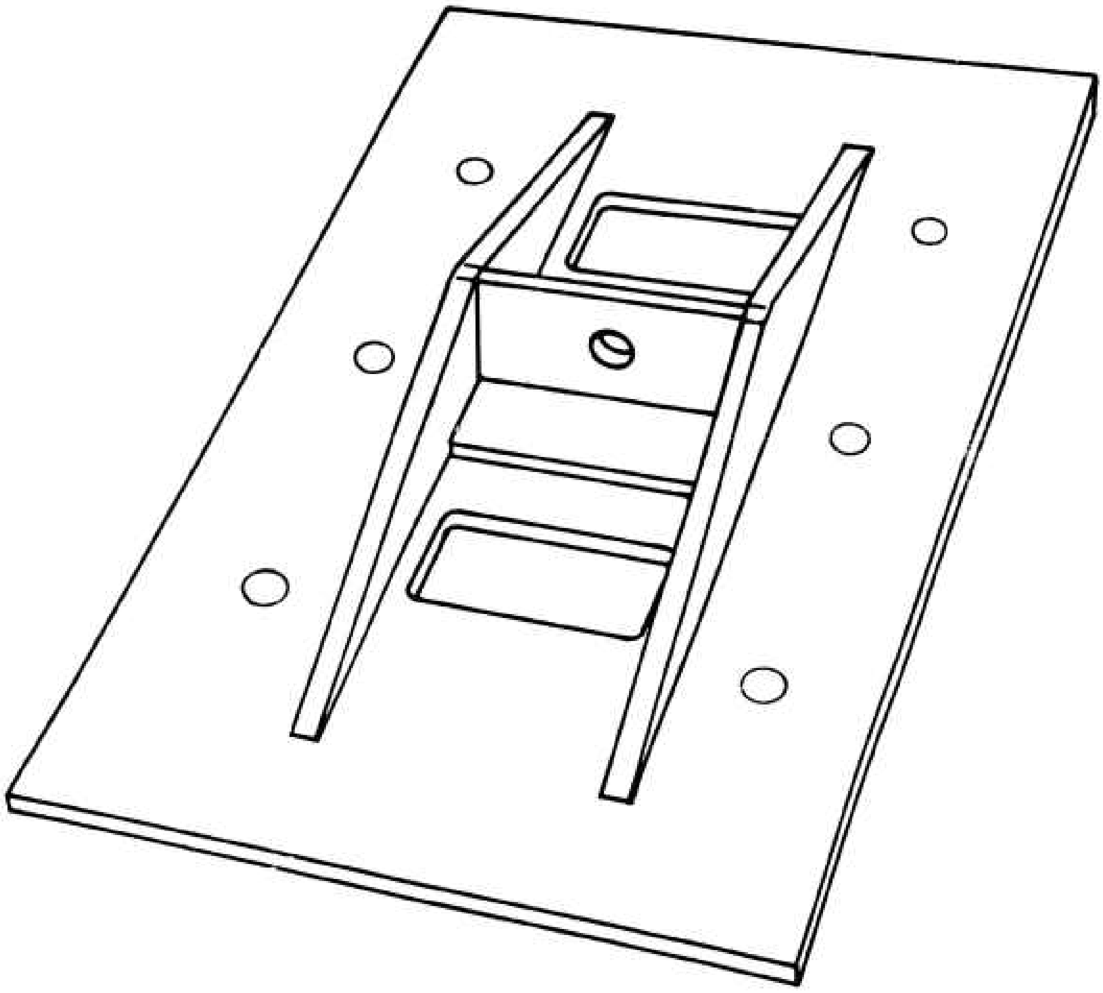


Figure 30. Modified Mounting Plate Design No. 2, Picture Frame with Gussets

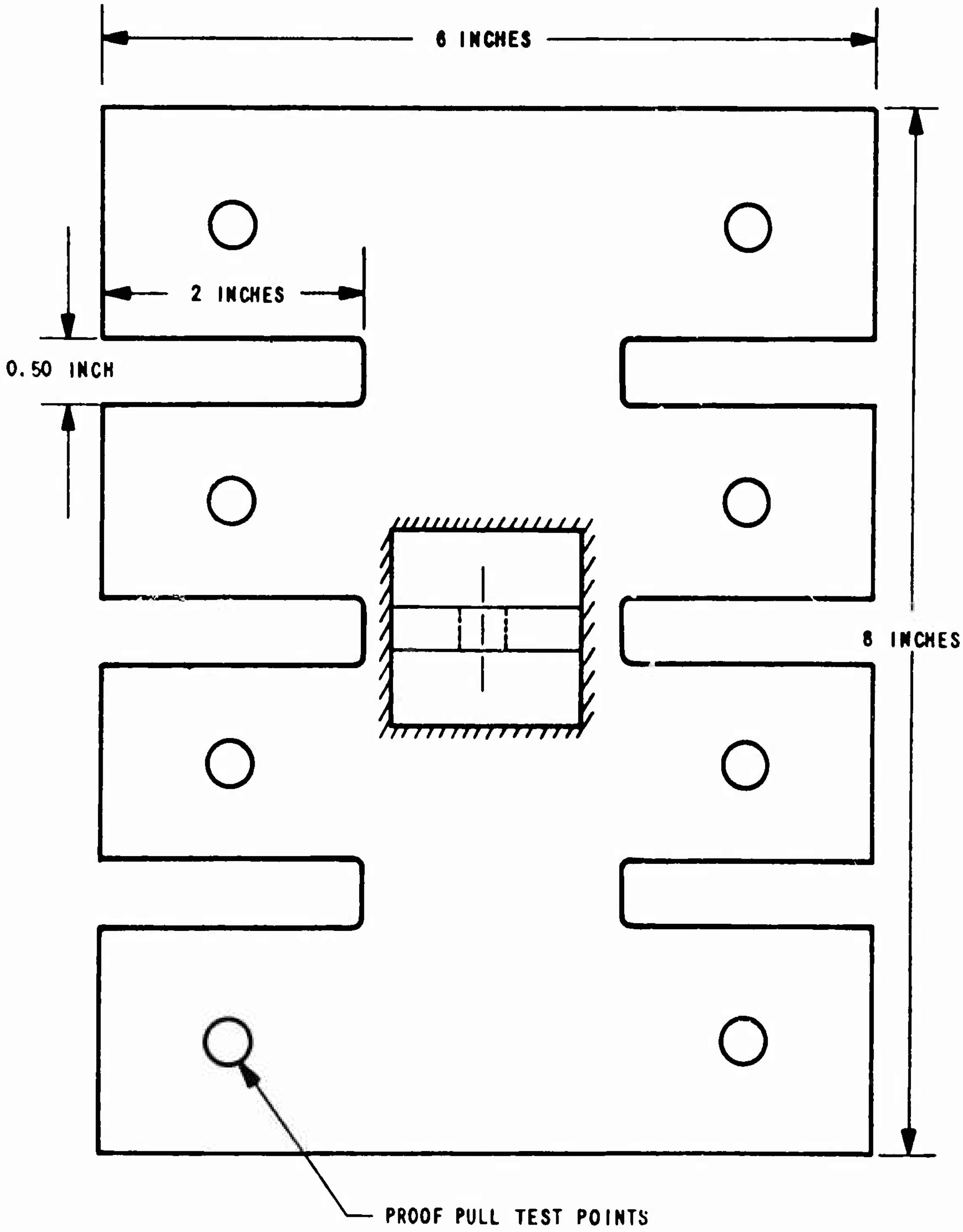


Figure 31. Modified Mounting Plate Design No. 3, Slotted Plate

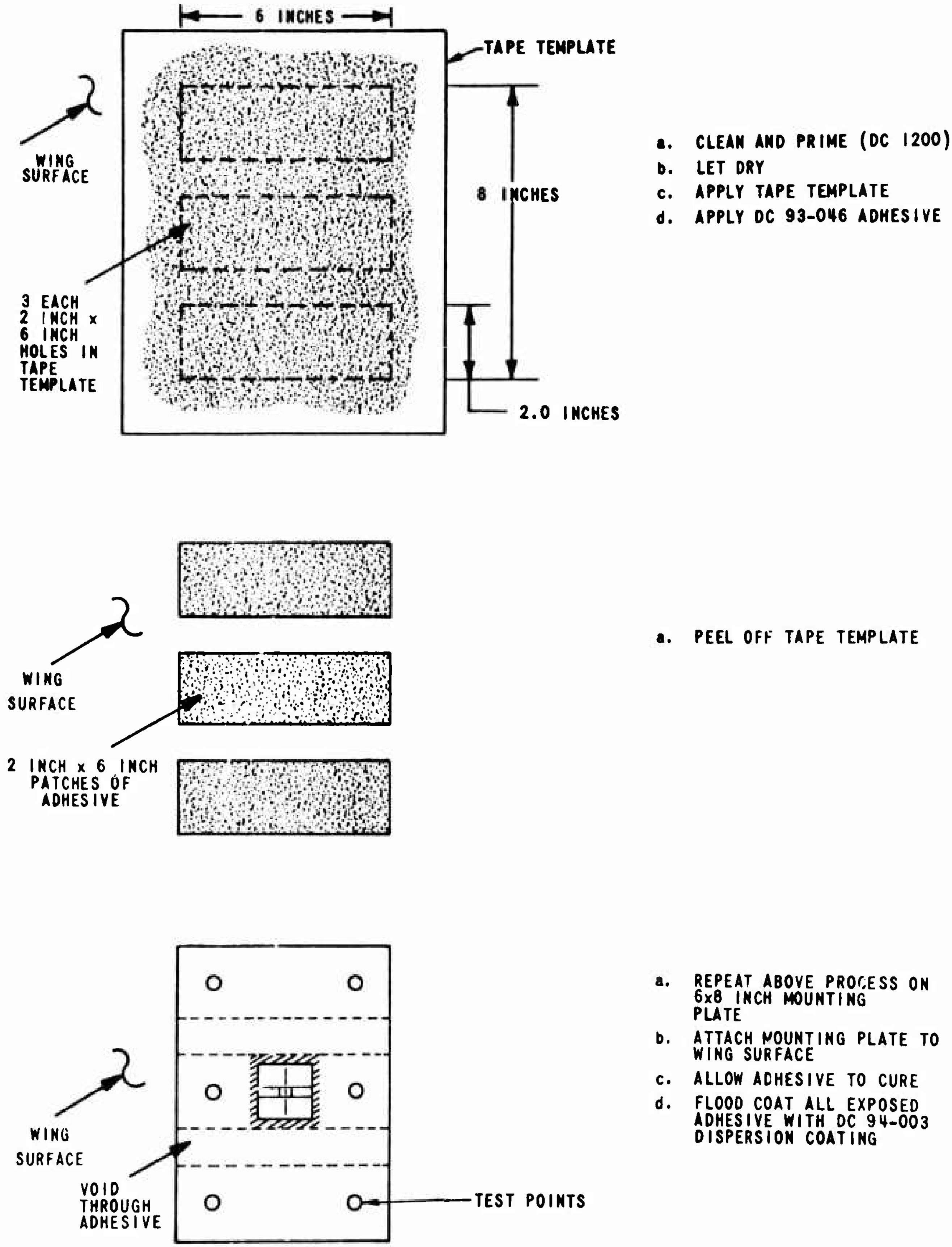


Figure 32. Modified Mounting Plate Design No. 4,
Individual Bonding Pads

The C-123K MISS was consequently installed and flight tested, using epoxy to attach the wing boom system and DC 93-046 silicone adhesive (protected with DC 94-002 fluorosilicone) to attach the engine exhaust, vent chute/dump chute, and fuselage hose assemblies. All systems worked as designed, and both bonding agents performed well. The components bonded with the silicone were easily removed during aircraft demodification, but the epoxy-bonded mounting plates remained in place as a permanent (Class V) aircraft modification.

4.1.3 Performance Degradation

Since the external MISS wing boom system will cause additional drag, several wing boom configurations were investigated. The drag coefficients for these shapes are shown in Figure 33, and the projected performance degradation in percentage of horsepower increase required to maintain cruise condition for several aircraft is shown in Table XI. As can be seen, a maximum increase of 3.4 percent horsepower is required to maintain cruise condition if a fully streamlined boom were used.

This data was then combined with actual hardware designs to develop a wing boom which was easily manufactured and exhibited minimal drag. The actual designs investigated are covered in paragraph 4.8.2 of this report. The final selection design was the aft fairing type, which was flight tested on a C-123K at Eglin Air Force Base, Florida. The pilot stated that additional drag was minimal and did not adversely affect flight characteristics.

4.1.4 Installation and Removal

Based on a review of ANA Bulletin 518, Cargo Aircraft Compartment Dimensional Data, the available aircraft T.O.'s, and other sources, a summary of data pertinent to MISS loading operations was compiled. Figure 34 and Table XII present this data for the specified aircraft. During loading, ANA Bulletin 518 specified that 6 inches clearance should be maintained between the cargo and the aircraft. Temporary wood shoring or tracks may be required to distribute the wheel loads on the aircraft floor, particularly in those cases where the treadways are spaced wider than the wheels. Several of the aircraft have built-in winches to assist loading. In the C-97, the winch is mounted on an overhead monorail and can be used to hoist cargo as well. Portable winches, either manual or power types, can be used on virtually all of the aircraft. However, these portable items are not a permanent part of the aircraft and, therefore, cannot be assumed to be available in all cases.

The tank and power modules are supplied with captive castors and jacks which facilitate installation and removal. These jacks and wheels were found to be extremely helpful during installation of the C-123K MISS at Eglin Air Force Base.

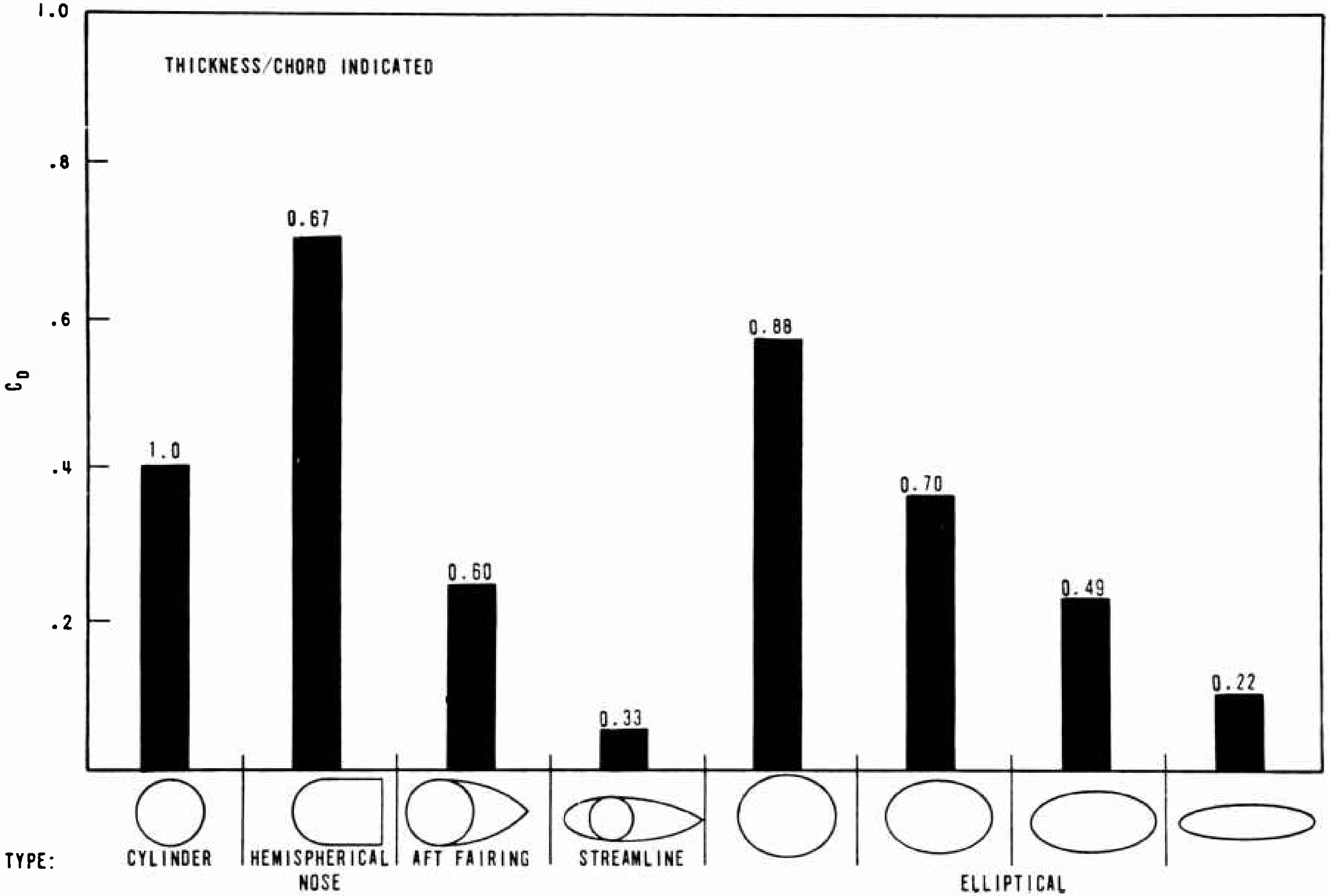


Figure 33. Wing Boom Drag Coefficient

TABLE XI. AIRCRAFT PERFORMANCE DEGRADATION AND HORSEPOWER INCREASE REQUIRED TO MAINTAIN CRUISE CONDITION USING STREAMLINED WING BOOM

			COMPONENT CONTRIBUTION AND TOTAL IN PERCENT					
AIRCRAFT	VELOCITY (KTAS)	ALTITUDE (FT MSL)	WING BOOM	BOOM BRACKETS	NOZZLE STATIONS	FUSELAGE STANDOFF	FUSELAGE NOZZLE	TOTAL
C-47D	142	5,000	2.40	2.25	1.62	0.11	0.11	6.5
C-54G	157	5,000	1.76	1.54	1.12	0.06	0.06	4.5
C-97G	198	5,000	1.76	1.48	1.15	0.05	0.05	4.5
C-118A	198	10,000	1.76	1.53	1.16	0.06	0.06	4.6
C-119G	151	5,000	1.04	0.98	.72	NIL	0.09	2.8
C-121G	212	10,000	1.64	1.45	1.08	0.06	0.06	4.3
C-123K	136	5,000	1.04	0.96	0.08	NIL	0.09	2.9
C-130E	263	20,000	2.00	1.75	1.31	NIL	0.14	5.2
C-131E	165	5,000	2.44	2.15	1.58	0.08	0.08	6.3

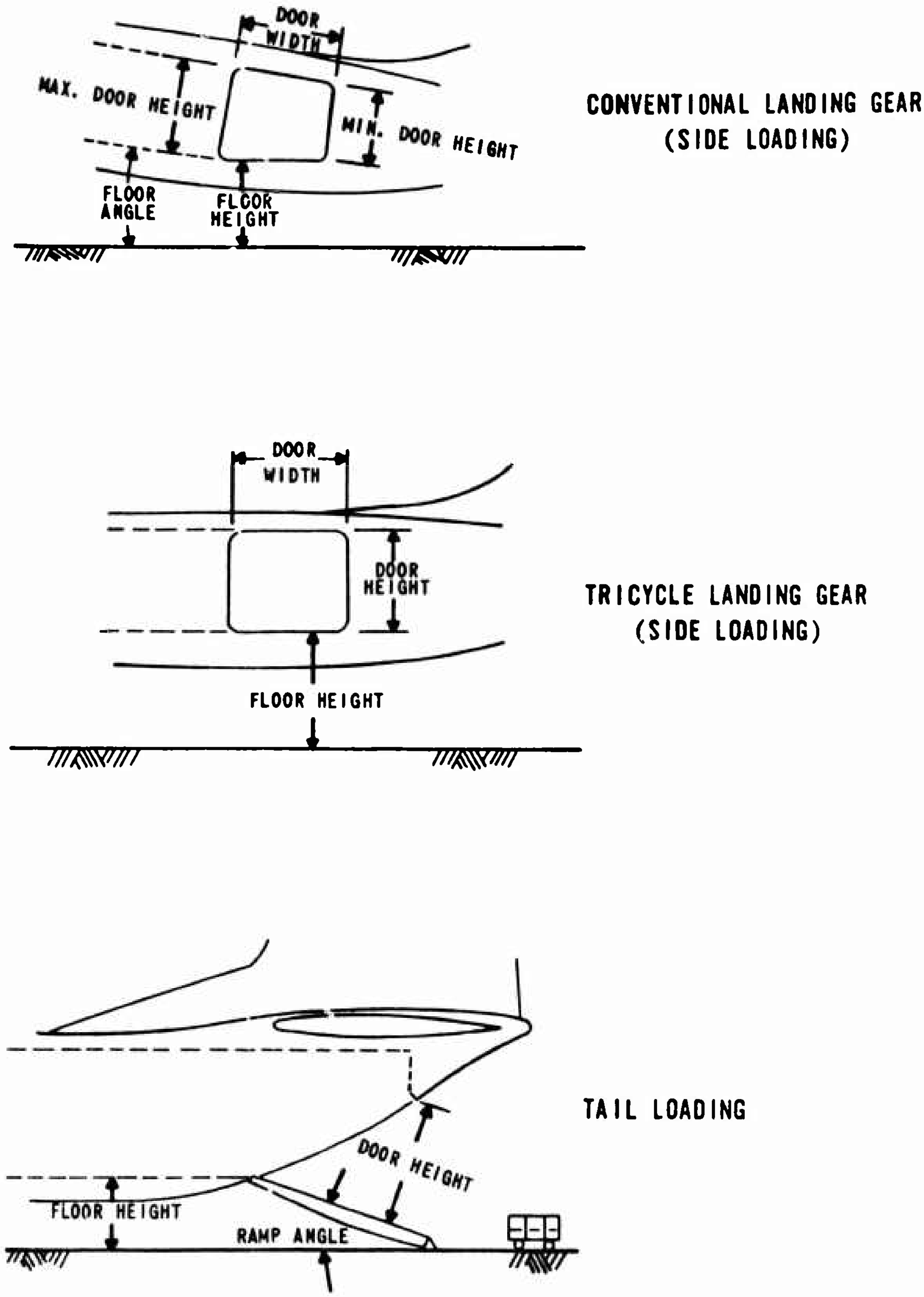


Figure 34. Aircraft Loading Nomenclature

TABLE XII. INSTALLATION/REMOVAL DATA

AIRCRAFT	MAIN DOOR	FLOOR ANGLE (DEGREE)	RAMP ANGLE (DEGREE)	FLOOR HEIGHT (INCH)	BUILT-IN WINCH	WINCH CAPACITY (POUNDS)	DOOR WIDTH (INCH)	DOOR HEIGHT (INCH)
C-46D	SIDE	9.5	N.A.	90-97 AT DOOR	NO	N.A.	81	69-79
+C-47D	SIDE	11.5	N.A.	56.5 AT DOOR	NO	N.A.	84.5	55.7 - 70.6
+C-54G	SIDE	(0)	N.A.	106.7	NO	N.A.	95	67
C-97G	AFT	(0)	24	112	YES WINCH/HOIST	7500/5000	(88)	84
C-118A	SIDE	(0)	N.A.	106	NO	N.A.	124	78
C-119G	AFT	(0)	10	45.5	YES	*	(110)	(92)
C-121G	SIDE	(0)	N.A.	112.5	*	*	112.5	74.5
+C-123K	AFT	(0)	12.5	33.5	YES	(3300)	110	98
+C-130E	AFT	(0)	12.5	41.6-45	YES	25,000	120	108
C-131E	SIDE	(0)	N.A.	89	NO	N.A.	100	72

NOTES:

+ - PRIMARY AIRCRAFT
N.A. - NOT APPLICABLE
* - NO DATA
( ) - NOMINAL OR APPROXIMATE

The installation and removal studies resulted in a required module envelope, as shown in Figure 35. The required and actual dimensions of the tank and power modules are shown.

The C-47 aircraft, due to its small size and side-loading cargo door, places the greatest restriction on the MISS design. During the design effort it became apparent that, to be cost effective and minimize the number of tank modules, the system would be a tight fit in the C-47. As a result, the tank module must be loaded from the end, as shown in Figure 36. During the fit test of the actual MISS hardware into the C-47, this end-loading technique was used successfully.

4.1.5 Aircraft Spray Contamination

Analysis of contamination possibilities on all ten aircraft was performed. Both normal spray operations and emergency dump were considered.

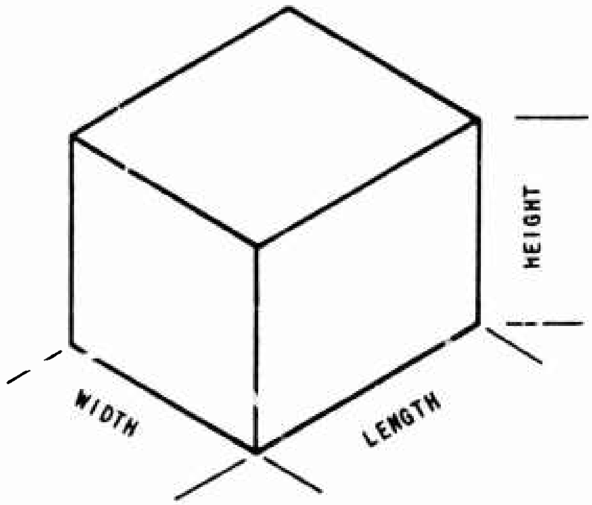
Small three-view drawings of the specified aircraft were used as an aid in this study. External MISS components were added to these drawings on the basis of preliminary component placement studies. The wing booms were 70 percent of the wing span in each case. Wing nozzle stations were spaced every eight feet on the booms, starting at the tip and working inboard. A minimum (of three nozzles) was used on each wing boom; on some long-span aircraft, four nozzles were used on each wing. Later design changes specified nozzles every 2 to 4 feet along the 70 percent span, but this design change does not affect the contamination data presented here.

To provide for fuselage spray stations on side-loading aircraft, a single central nozzle station extending down from the open cargo door was used. On tail-loading aircraft, a pair of central nozzle stations were used, with one nozzle extending outward from each open jump door.

The dump line was assumed to be mounted in the open cargo or jump door, with the end of the tube protruding only slightly from the fuselage line.

Normal spray patterns were superimposed on the drawings using an arbitrary expanding conical form. If portions of the aircraft appeared to fall within these spray patterns, a contamination possibility was assumed to exist.

Likewise, the estimated dump pattern was superimposed on the aircraft and contamination possibilities were investigated.



DESCRIPTION	ALLOWED	POWER MODULE	TANK MODULE
① LENGTH (INCHES)	85	60	72
② WIDTH (INCHES)	49	52*	48
③ HEIGHT (INCHES)	64	56	63.5

① = DETERMINED FROM C-47 LOADING CHARTS.

② = DETERMINED FROM C-47 COMPARTMENT WIDTH OF 79 INCHES - ALLOWS 2 - 15 INCH AISLES.

③ = DETERMINED FROM C-47 CARGO DOOR.

* = POWER MODULE OFFSET IN C-47 TO ALLOW ONE AISLE 15 INCHES WIDE .

Figure 35. Module Envelope

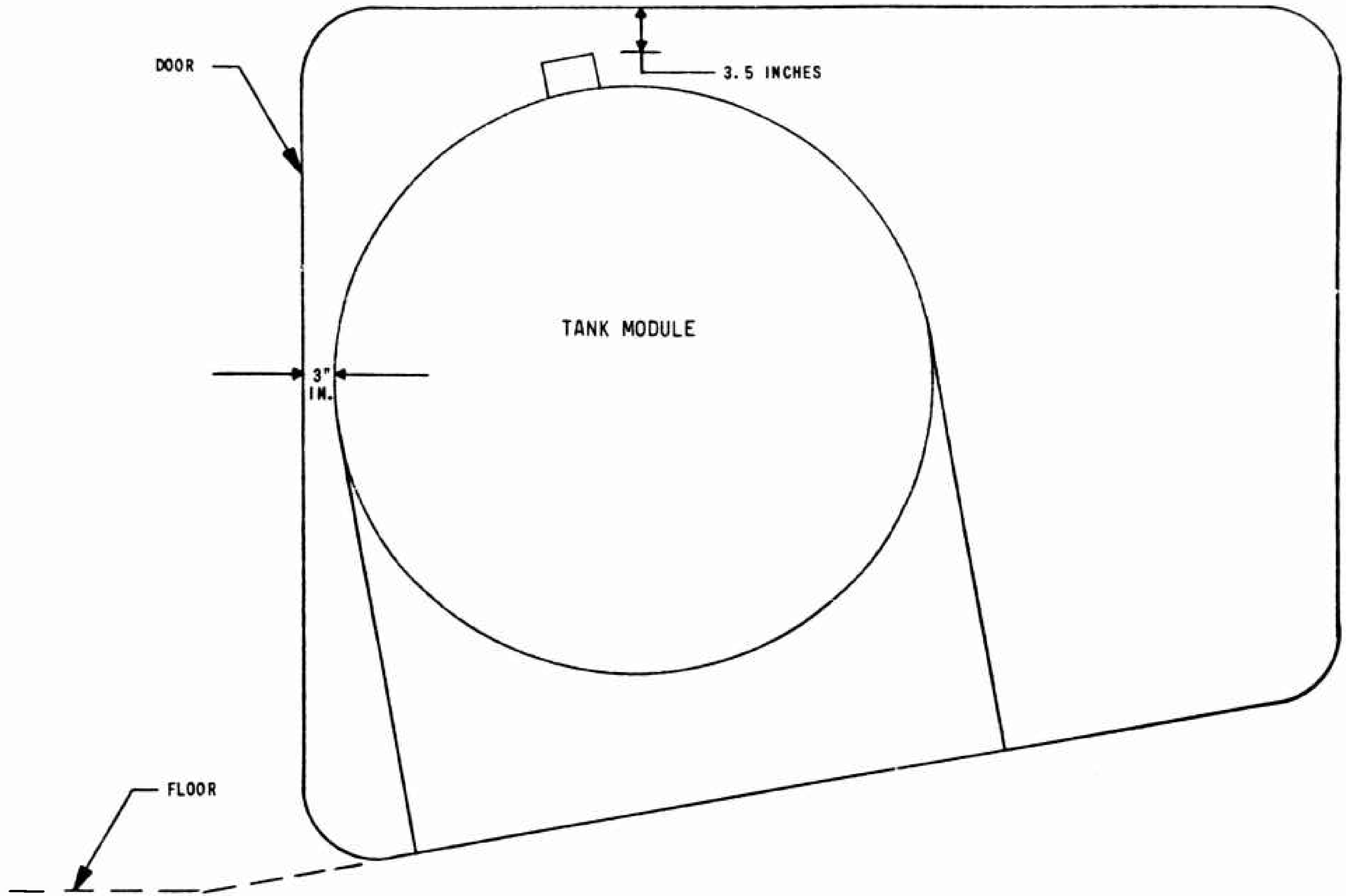


Figure 36. C-47 Installation

The results of the study are summarized in Table XIII. Note that three spray nozzle orientations are considered, ranging from straight aft to straight down. It appeared that a 45-degree down or straight-down orientation was attractive from the standpoint of reducing the possibility of wing contamination. The actual nozzle orientation selected was straight down.

Emergency dump contamination, although present, is not considered to be a significant problem due to the overriding safety requirements for the dump.

Results of the flight test of a C-123K Modular Internal Spray System at Eglin Air Force Base, Florida, indicated that:

1. No contamination resulted from the wing boom nozzle stations.

2. The right-hand fuselage nozzle station caused minor contamination of the right-hand aft fuselage (apparently due to the vacuum created by the dump chute directly behind the nozzle station or due to the aircraft propeller rotation direction).

3. The emergency dump caused contamination of the aft fuselage up to the horizontal stabilizer, and slight internal contamination due to sprayback through the jump doors. All personnel present at the flight tests agreed that moving the dump chute to the rear of the jump door would prevent internal contamination. The dump chute was relocated accordingly on subsequent MISS kits.

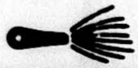
4.1.6 Spray Performance

Contractual requirements stated that the effective ground swath width must be at least twice the applicable aircraft wing span when agent is disseminated at 100 feet above ground level (AGL). To accomplish this, it is necessary to take advantage of the dispersing effects of the wing tip vortices.

Figure 37 illustrates the general nature of these vortices. As the vortex moves aft, it expands, forming a conical pattern. The swirling effect causes agent introduced into the vortex to disperse laterally. The size and strength of the vortex depends upon flight conditions and the specific aircraft but, in general, it can be expected to cause sufficient lateral dispersion to meet the swath width requirement.

Propwash also can be expected to cause agent swirl, but generally it is not sufficient to guarantee a wide swath.

TABLE XIII. CONTAMINATION POSSIBILITIES

AIRCRAFT	NORMAL SPRAY OPERATIONS			EMERGENCY DUMP
	NOZZLE ORIENTATION			
	STRAIGHT AFT 	45° DOWN 	STRAIGHT DOWN 	
C-46D	A, B	B	B	C, D
C-47D	A, B	B	B	C
C-54G	A, B	B	B	C
C-97G	A	0	0	C
C-118A	A, B	B	B	C
C-119G	A, G	G	G	0
C-121G	A	0	0	C
C-123K	A, B	B	B	C, E
C-130E	A, B	B	B	C, E
C-131E	A, B	B	B	C, F

NOTES:

0 = NO CONTAMINATION ANTICIPATED

A = POSSIBLE CONTAMINATION OF LOWER WING SURFACE ABOVE AND AFT OF NOZZLES

B = POSSIBLE CONTAMINATION OF TIP OF HORIZONTAL STABILIZER

C = LIKELY CONTAMINATION OF FUSELAGE SIDE

D = LIKELY CONTAMINATION OF HORIZONTAL STABILIZER (LOWER SURFACE)

E = POSSIBLE CONTAMINATION OF EXTERIOR OF CARGO RAMP

F = POSSIBLE CONTAMINATION OF LOWER SURFACE OF HORIZONTAL STABILIZER

G = POSSIBLE CONTAMINATION OF TAIL BOOM

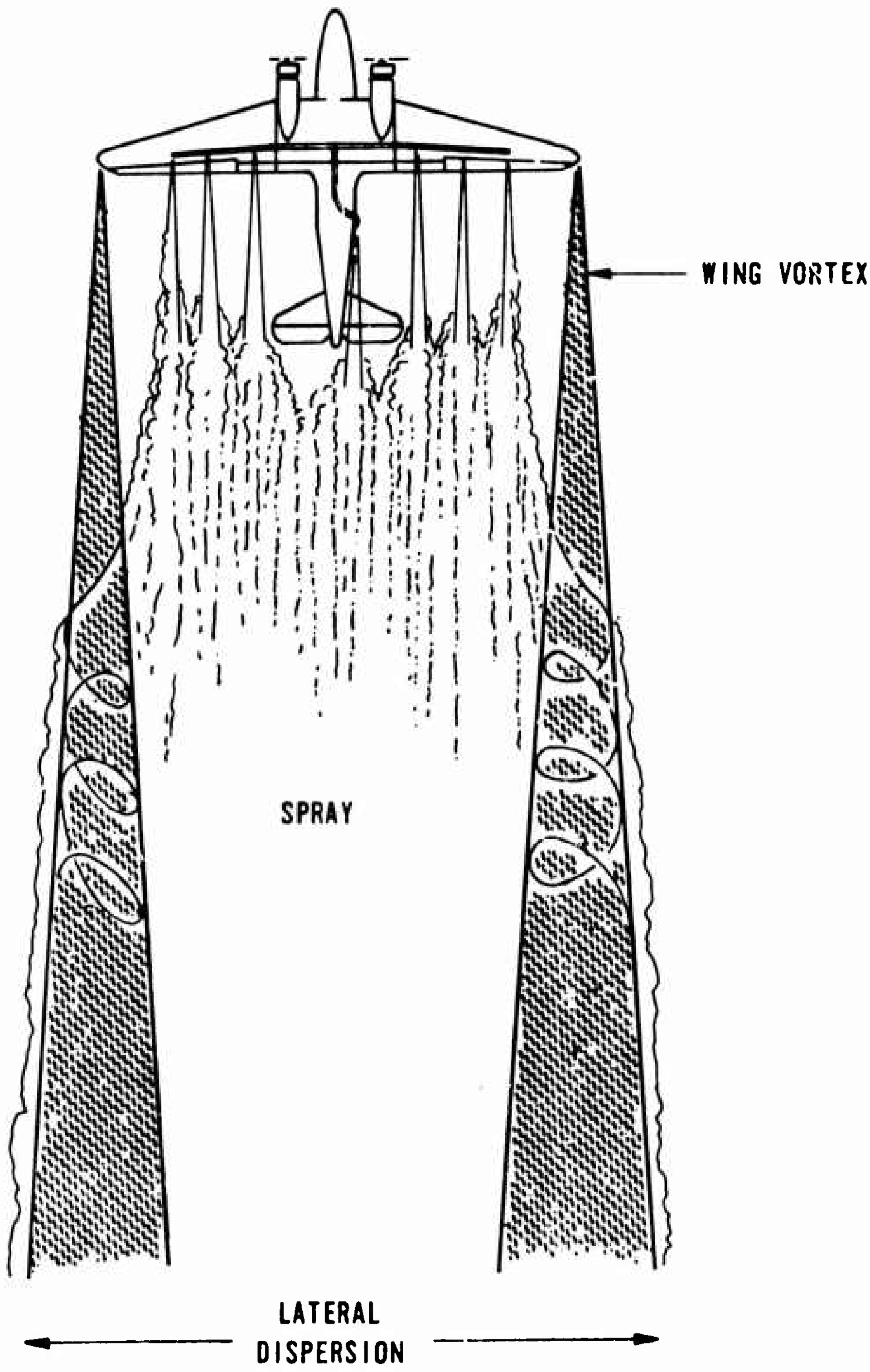


Figure 37. Wing Vortex Effect

A relatively uniform deposition level over the swath width is important for avoiding undue agent concentrations or voids. If a single tail spray nozzle station is used, a large peak would be expected along the aircraft flight path.

It should be noted that effective swath width differs from total swath width, as illustrated in Figure 38. For efficient spraying, it is therefore desirable to have relatively uniform deposition curve with steep ends.

It must be pointed out that nozzle placement can have an effect on the ground spray pattern and therefore warranted investigation. However, nozzle placement can never be expected to achieve a perfect ground pattern, for it cannot overcome or change the basic airflow characteristic of a given aircraft. These characteristics determine the gross ground spray effects.

Spray performance data was generated as an aid to design studies. This data was based on a nominal spray speed of 150 mph and assumed ideal conditions in that all agent sprayed was to be evenly distributed in a swath width equal to twice the aircraft wing span with no peaks or valleys. Table XIV presents the spray performance data. Note that the 3 ounce/acre deposition columns were based on four times the aircraft wing span. This is justified by previous low volume spray testing results, which show greater lateral drift of the fine low volume spray.

Using the specified extremes of agent deposition, flow rates were calculated. Based on total agent capacity and flow rate, maximum spray time was computed for both deposition level extremes. From a practical standpoint, the spray times for the 3 ounce/acre deposition level are far in excess of normal mission time. In fact, they generally exceed the maximum airborne endurance capabilities of the aircraft. Maximum area coverage was then calculated, based on spray time and area coverage rates.

To actually achieve effective swath widths equal to those shown, it will be necessary to spray at greater than the indicated flow rates (due to deposition peaks and trail-off), which will, in turn, reduce spray time and area coverage figures.

4.2 CHEMICAL AGENTS

Contractual requirements dictated that the PWU-5/A MISS was to disseminate a variety of chemical agents, including defoliants, herbicides, pesticides, and fertilizers in the form of chemical solutions, suspensions and slurries. The range of physical properties for these agents as stated in the contract were:

PROPERTY	RANGE LOW	RANGE HIGH
Specific Gravity	1.0	2.0
Viscosity, Centipoise	1	350

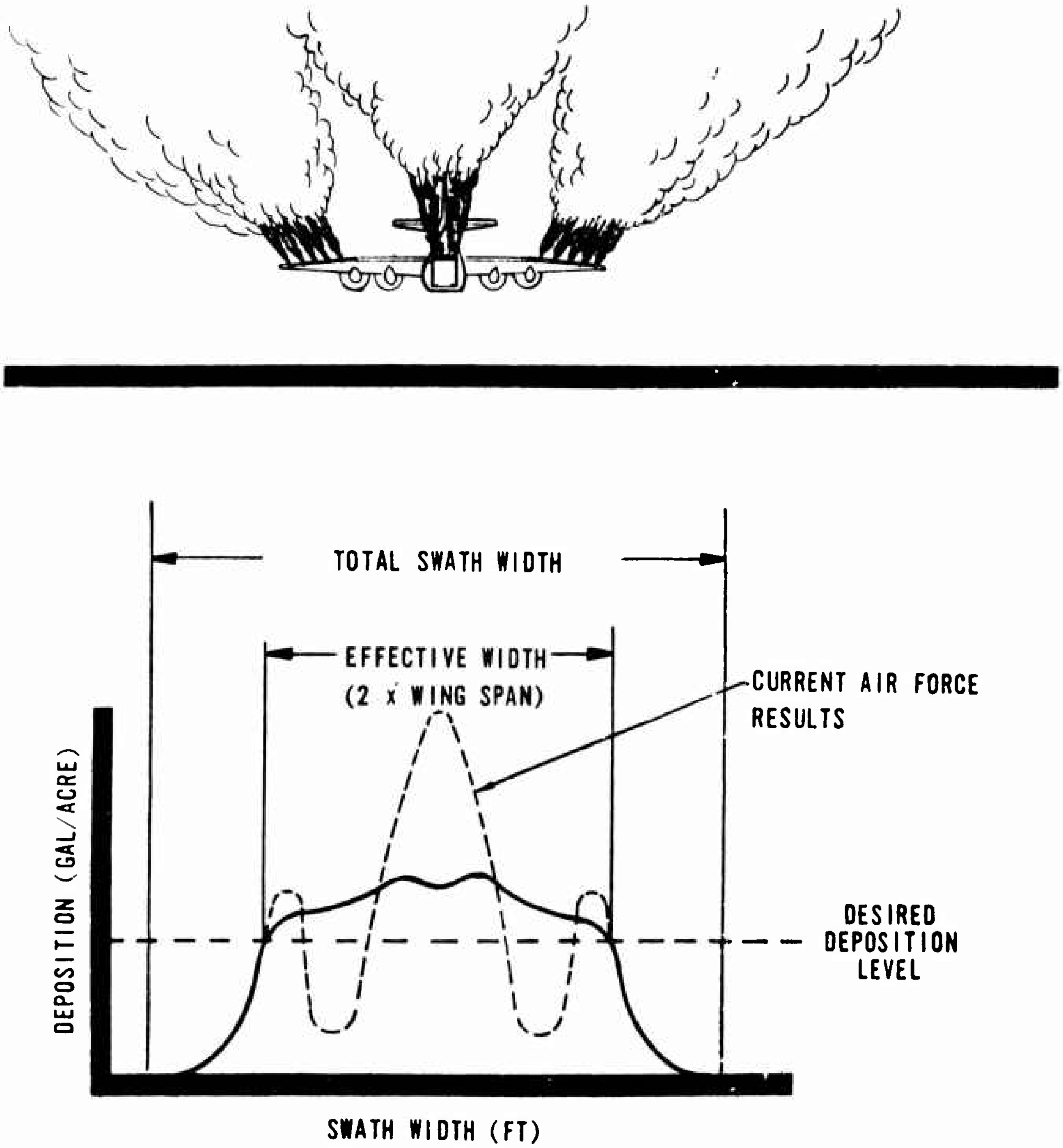


Figure 38. Effective Swath Width

TABLE XIV. SPRAY PARAMETERS

AIRCRAFT VELOCITY = 150 MPH RECTANGULAR DISTRIBUTION SPECIFIC GRAVITY = 1.0

AIRCRAFT	SWATH WIDTH (FT)	AGENT CAPACITY (GAL)	FLOW RATES		SPRAY TIME		AREA COVERAGE	
			3 OZ/ACRE + (GPM)	3 GAL/ACRE (GPM)	3 OZ/ACRE + (MIN)	3 GAL/ACRE (MIN)	3 OZ/ACRE (ACRES)	3 GAL/ACRE (ACRES)
C-46D	216	1024	3.06	196	335	5.3	43,700	345
C-47D	190	480	2.7	173	178	2.7	20,600	158
C-54G	235	1924	3.34	214	576	9.0	82,000	637
C-97G	283	3550	4.02	257	883	13.7	151,000	1180
C-118A	235	2592	3.34	214	776	12.1	110,000	860
C-119G	219	1752	3.10	199	735	8.7	74,600	579
C-121G	246	2592	3.48	224	745	11.6	112,000	870
C-123K	220	992	3.12	200	318	5.0	42,500	334
C-130E	265	3968	3.76	241	1053	16.5	169,000	1320
C-131E	211	960	3.00	192	320	4.6	37,500	292

+ BASED ON FOUR TIMES WING SPAN.

4.2.1 Agent Characteristics

Using the above requirements, a survey of existing and potential future chemical agents was made to determine their chemical, physical, and toxicity characteristics. Table XV lists several such agents. As can be seen, most agents have specific gravities less than 1.5 and viscosities less than 50 centipoise. Although there were no contractual toxicity requirements, the agent toxicity was a necessary consideration to provide a system which is safe for operating personnel. As shown in Table XV, certain of the pesticides have high toxicity. This toxicity dictated that the MISS agent transfer system be sealed to prevent agent or agent vapor leakage inside the aircraft. As a result, sanitary-type plumbing connections were used throughout the system and the tankage venting system was sealed and designed to vent harmful vapors overboard.

Many of the wettable powder and suspension-type agents tend to settle if not agitated constantly. Agitation can be mechanical or can be accomplished by agent recirculation of at least 10 percent of the tankage volume per minute. The recirculation method was chosen for the MISS since it could be easily and inexpensively accomplished with the MISS centrifugal pump dissemination system. The MISS can recirculate over 500 gpm (250 gpm through each 500-gallon tank) and therefore provide 50 percent tank volume recirculation. In addition, the tank agent pickup lines are designed to provide maximum agitation at the bottom of the tanks, allowing remixing of any settled agents.

The contractual requirements for suspension and slurry-type agents also dictated the use of abrasion-resistant materials and mechanical-type pump seals in the agent transfer system.

Of particular interest is the capability requirement for s- type agents. Investigation into the various possible agen showed that the only true slurry-type agents were certain advance fertilizers which exhibited thixotropic viscosity characteristics, as shown in Figure 39. As can be seen, these fertilizers had viscosities well above the 350-centipoise contractual limit. In addition, these fertilizer slurries were extremely abrasive and would severely limit mechanical component life if used.

Table XVI shows several of the MISS agents and their typical application rates. As can be seen, they all fall within the 3 ounces to 3 gallons per acre contractual application rate requirement.

4.2.2 Agent/Material Compatibility

The chemical nature of the applicable MISS agents dictated certain system materials. Several materials were laboratory tested at room temperature and reflux temperatures with the chemical agents. Both the corrosive and solvent action of the materials were

TABLE XV. PWU-5/A MODULAR INTERNAL SPRAY SYSTEM AGENTS

AGENT NAME	SPECIFIC GRAVITY	VISCOSITY, CENTIPOISE	TOXICITY* LD_{50}, mg/kg	PRODUCT FORM
DEFOLIANTS				
AGENT ORANGE	1.28	43	550	LIQUID
AGENT WHITE	1.14	<140	3,030	LIQUID
AGENT BLUE	1.336	12.5	1,600	WATER SOLUTION
HERBICIDES				
TANDEX	1.5	350	3,000	WP
PESTICIDES				
MALATHION	1.2315	36	2,800	EC, WP, LOW VOLUME (LV)
FENTHION	1.245	<50	190-350	LV
DIBROM	1.842-1.846	28	450	LV, EC, DUST
DURSBAN	1.062-1.175	3-18	135	EC,
FERTILIZER				
N-Sol 32 (Urea-NH_4NO_3)	1.327	2.0	NONE	WATER SOLUTION
UREA SOLUTION 50%, 45%	1.158	2.0, 1.8	NONE	WATER SOLUTION
AMMONIUM PHOSPHATE	1.36	29	NONE	WATER SOLUTION
14-14-14 SUSPENSION	1.404	280	>5000	WATER SUSPENSION

* HIGHLY TOXIC LD_{50} = 1-20 MODERATELY TOXIC LD_{50} = 150-750 SLIGHTLY TOXIC LD_{50} = 800-3000

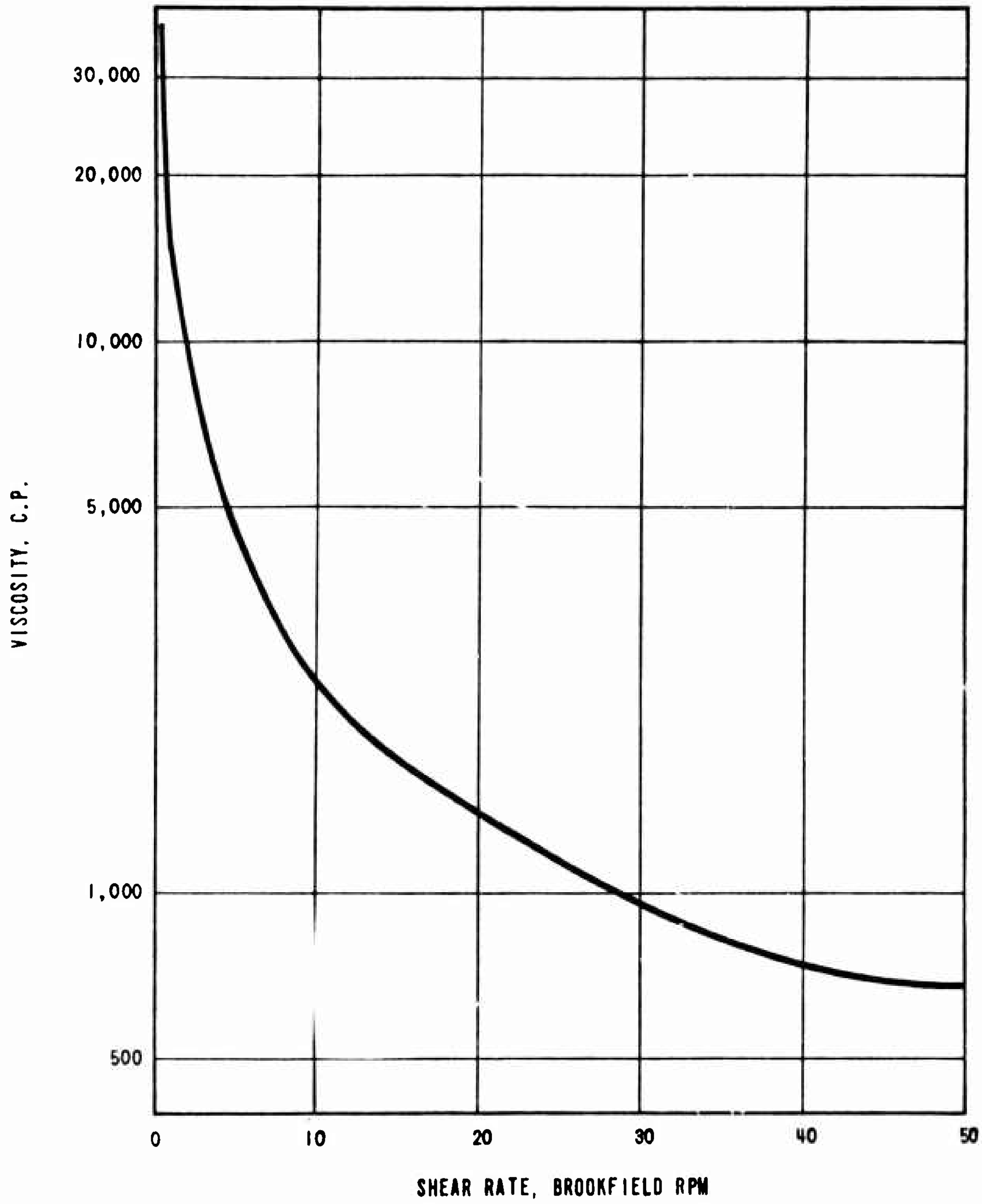


Figure 39. Thixotropic Nature of Slurried Fertilizer

TABLE XVI. AGENT APPLICATION RATES

AGENT	APPLICATION RATE	PRODUCT FORM
CONTRACT REQUIREMENTS	3 OZ TO 3 GAL/ACRE	SUSPENSION, SOLUTION, SLURRY
DEFOLIANTS		
ORANGE	3 GPA	LIQUID
WHITE	3 GPA	LIQUID
BLUE	3 GPA	WATER SOLUTION
HERBICIDES		
TANDEX	1-2 GPA	WETTABLE POWDER
PESTICIDES		
MALATHION	3 OZ/ACRE	LV
FENTHION	6 OZ/ACRE	LV
DIBROM	3 OZ/ACRE	LV
DURSBAN	3 OZ/ACRE	LV
FERTILIZERS		
UREA	3 GPA	WATER SOLUTION
14-14-14	1-2 GPA	WATER SUSPENSION

investigated, and the results of these tests were combined with previously collected data to analyze the select cost-effective piping, valving, tankage, sealing, and hose materials. The results of the most applicable tests are shown in Table XVII.

Previous studies involving defoliants for military use indicated that Agent Blue has a heavy corrosive action upon aluminum and eliminated it as a candidate material without costly and troublesome protective coatings. Investigations of MF-1, 401, 301, 304, and 316 stainless steels indicated the use of 304 or 316 stainless for tanks and piping. The 304 was selected as being more cost effective.

Several plastic and elastomeric materials were investigated for use as seals, bushings, valves, hoses, etc. The results indicated that Teflon® , nylon, and cross-linked polyethylene were the most stable plastics, while fluorosilicone was the only truly acceptable elastomer (mostly due to the Xylene content of certain insecticides).

Another problem concerning agent-material compatibility is the availability of the compatible materials in a usable and cost-effective product. As an example, cross-linked polyethylene is cost-effective and was used for high-pressure hoses, but it is not available for seals or flexible enough for suction hoses. Teflon® was used for the centrifugal pump mechanical shaft seal and several valve seals (suitably reinforced with isolated elastomeric material), since it was chemically compatible and available from manufacturers in those product forms. Custom seals, such as for the tank manhole, were compression molded from fluorosilicone. Nylon was utilized for nozzle valves. Silicone, reinforced with fiberglass cloth, was selected for the dump and vent hoses after laboratory testing with pure Xylene. Teflon® could have been used but was prohibitively expensive.

4.3 AGENT TRANSFER SYSTEM

The agent transfer system consists of all those components which contain, move, or control the agent on board the aircraft. Section III of this report contains a description of the final MISS agent transfer system and the related pneumatic and electrical systems. The MISS Operation and Maintenance Manual contains a complete description of each agent transfer system operation.

Several major design changes were made to the agent transfer system during the course of the contract. Changes were made to either increase system flexibility and performance or decrease cost.

From the origination of the contract, a gasoline engine-driven centrifugal pump was selected as the best method for moving the agent. A pneumatic agent expulsion system was considered, but it was eliminated due to the complexity and danger of such a system

TABLE XVII. PWU-5/A MODULAR INTERNAL SPRAY SYSTEM AGENT COMPATIBILITY

SUBSTRATE	INSECTICIDES			HERBICIDES			FERTILIZERS
	DIBROM	MALATHION	DURSBAN	ORANGE	WHITE	BLUE	
METALS							
ALUMINUM	■□ UNCHANGED	NOT SIG.	NOT SIG.	NO EFFECT	NO EFFECT	V. SIG.	EROSION FROM ADRASION
MILD STEEL (UNLINED)	HIGH SIG.	SIG.	SIG.	NOT SIG. (IF ACID FREE)	SIG.	SIG.	NOT SIG.
STAINLESS STEEL	■□ 304 NOT SIG. □ 316 NOT SIG	NOT SIG.	■ NOT SIG.	PASSIVE COATING FORMED IN MANY CASES.			EXCEL. ABRASIVE RESISTANCE
PLASTIC							
NYLON 66			UNCHANGED	WITHSTANDS SOLVENT SWELLING & CRAZING			
PLEXIGLAS	UNCHANGED	N.A.	UNCHANGED	SOLVENT CRACK'G & DISSOLUTION EVIDENT			
POLYPROPYLENE	N.A.	NOT SIG.	V. SLIGHT	WITHSTANDS SOLVENT SWELLING & CRAZING			
CROSSLINKED POLYETHYLENE	SLIGHT	SLIGHT	SLIGHT	WITHSTANDS SOLVENT SWELLING & CRAZING			
MODIFIED CROSSLINKED POLYETHYLENE	NOT SIG.	NOT SIG.	NOT SIG.	WITHSTANDS HERBICIDE AGENTS			
TEFLON	UNCHANGED	UNCHANGED	UNCHANGED	DOES NOT REACT WITH STD AG CHEMICALS			
ELASTOMERS							
POLYURETHANE	SIG.	SIG.	V. SIG.	SOLVENT SWELLING IN THESE AGENTS			
EPR	N.A.	VERY SIG.	SIG.	SOLVENT SWELLING IN THESE AGENTS			
SILICONE RUBBER	NOT SIG.■	NOT SIG.■	NOT SIG.■	NOT AFFECTED BY HERBICIDE AGENTS			
FLUOROSILICONE RUBBER	UNCHANGED	UNCHANGED	NOT SIG.	NOT AFFECTED BY HERBICIDE AGENTS			

NOTES:
■AS LONG AS PASSIVATED AND THE COATING IS INTACT.
□NOT TO BE USED FOR STORAGE.
■IF NOT FORMULATED WITH XYLENE. XYLENE 25 PERCENT SWELLS.

and because a pneumatic expulsion system could not provide agent agitation as required for the various wettable powder suspension-type agents. A centrifugal pump was selected for its inherent safety (can be run at stall conditions) and because it could pump suspension-type agents without being damaged.

Figure 40 shows the agent transfer system schematic as originally proposed. This system used a single agent reservoir assembled from two end sections and several center sections depending on the load-carrying capacity of the aircraft. Filling was done directly into the tank using peripheral ground support equipment. Tandem centrifugal pumps were used and agent control valves were electrically operated. A single electromagnetic induction-type flowmeter was used to monitor agent flow. Wing boom nozzle valves with spring-loaded poppets were proposed to seal agent at the nozzles when dissemination was stopped. One large dump valve was employed, and an air tank was used to pressurize the tank during emergency dump to decrease dump time.

Detailed investigation of the center-of-gravity requirements for all ten aircraft indicated that a single tank could not adequately maintain fluid center of gravity, and a multiple tank concept was generated. Two sets of tanks were used, one set on each side of the power module. Each set of tanks was connected in series, and each set was provided with its own pickup (power module pump suction) and recirculation connections. By providing each tank with a remotely actuated vent valve, fluid movement could be controlled by opening or closing certain tank vents. Closing all tank vents prevented movement of agent between tanks and fulfilled the aircraft center of gravity requirement. Opening the vent on the tanks furthest from the power module (outside tanks on both sides) allowed the tanks to sequentially empty from the furthest outside tanks to the tanks nearest the power module during dissemination. Closing the end tank vents when dissemination was stopped prevented further agent movement between tanks even with the agent being recirculated through both sets of tanks. This multiple tank concept with tank vent valves was utilized in the final PWU-5/A Modular Internal Spray System.

Figure 41 shows the multiple tank system as used in the second major agent transfer system concept, which included several major changes over the original concept (Figure 30). A single large capacity centrifugal pump replaced the previous tandem pumps to decrease hardware costs and weight. The centrifugal pump was also used to suction fill and power drain the system, and a small ground pump was used for pump priming. Agent control valves were pneumatically operated with air being supplied by a pneumatic system built into the power module. The emergency dump valves on each tank were also pneumatically operated, but the air pressure was supplied by an isolated air reservoir which would maintain pressure even if the primary air system failed (leaked). The concept of pressurizing the tanks during emergency dump was eliminated due to the large volume of compressed air required and the

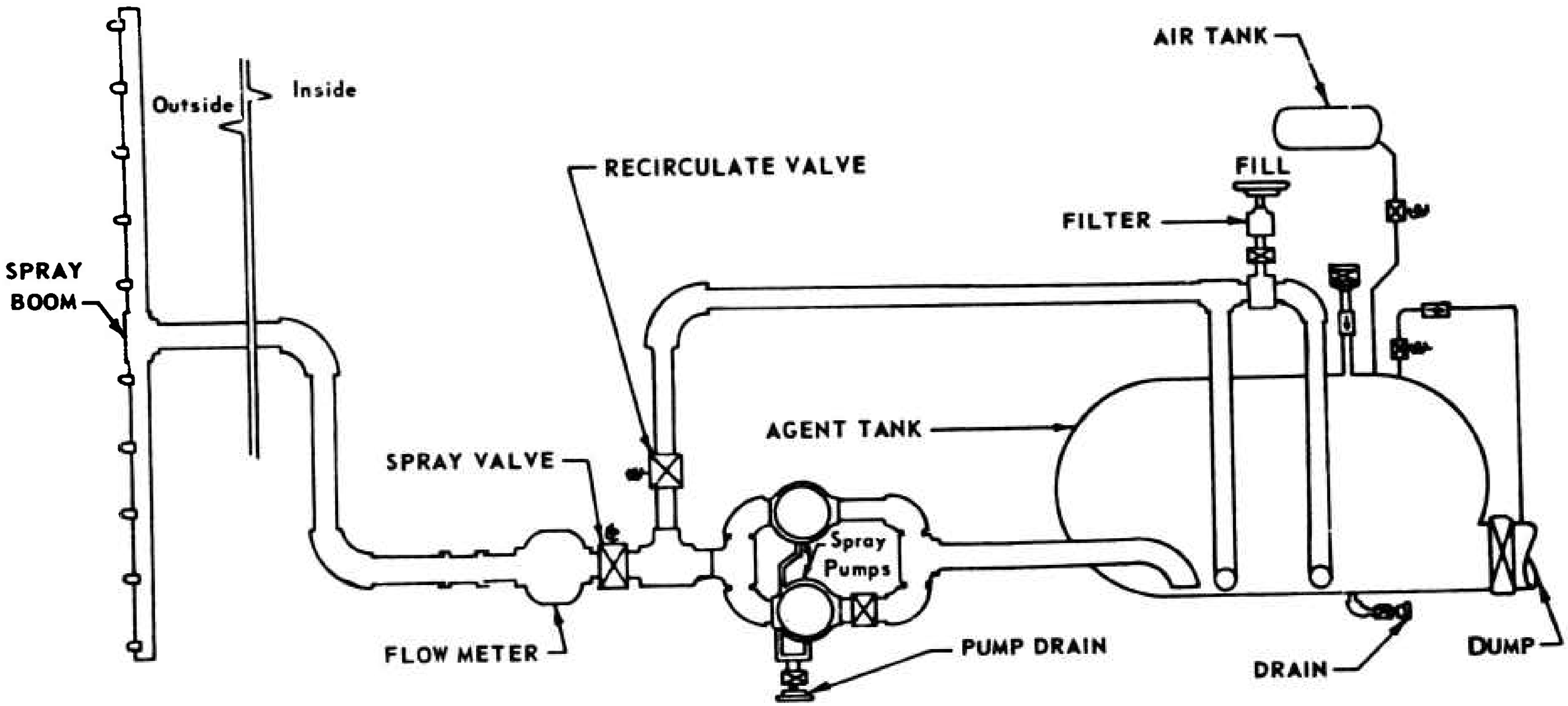


Figure 40. Agent Transfer System (Original Proposed Concept)

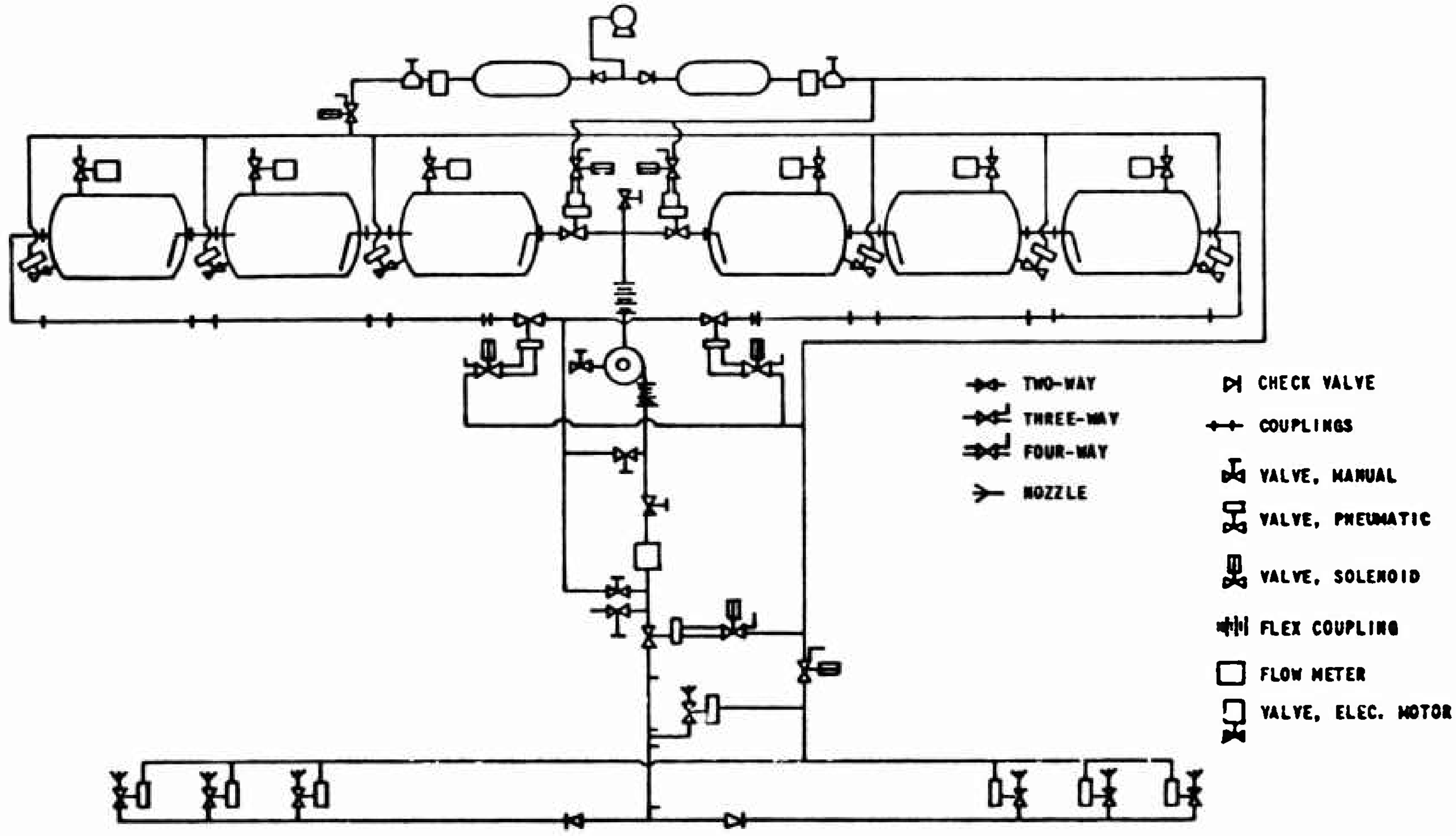


Figure 41. Agent Transfer System (Second Concept)

system complexity. Tank vent valves were electric motor-driven ball valves, selected to minimize hardware costs and complexity and also provide positive feedback indication of their open or closed position to the operator control panel. An electromagnetic induction flowmeter was used in conjunction with a flow totalizer to indicate total fluid volume on board at any given time. Pneumatically assisted diaphragm check valves were installed at each wing boom nozzle to provide absolute agent shutoff after dissemination and assure no agent leakage at the nozzles even when the aircraft underwent maximum airborne maneuvers.

The agent transfer system was further refined as shown in Figure 42. As a result of flow model tests (paragraph 4.4 of this report), the pneumatically operated recirculation line valves were eliminated and the agent pickup (tank suction) valves were changed from pneumatically operated to manual in order to reduce system complexity. The small ground pump, used to prime the main centrifugal pump, was eliminated in favor of an air-activated eductor which used the primary power module air system pressure to create a vacuum in the centrifugal pump and draw agent into the pump. Adoption of the eductor greatly simplified the system and ground support operations and allowed the centrifugal pump to be easily primed at any time, even if prime were lost during system operation.

Figure 43 shows the fourth agent transfer system concept. The pickup tubes inside the tanks were changed so that both tubes in each tank picked up agent off the tank bottom. This was done to increase system flexibility by allowing the suction and recirculation connections at the tank to be interchanged for different aircraft applications as required. Also, this positioning of the tubes provides maximum agitation (during recirculation) at the bottom of the tank to insure complete mixing and suspension of wettable powder-type agents. The electromagnetic induction flowmeter system was eliminated because several spray agents did not exhibit sufficient electrical conductivity, the induction flowmeters could not withstand airborne vibrations, and the peripheral equipment for the induction flowmeters was extremely heavy and costly. Dual turbine flowmeters were selected to monitor agent dissemination rate. The low volume system reads agent flow rates from 0 to 60 gpm and includes a fine mesh agent strainer. The high volume system reads 0 to 600 gpm. Dual flowmeters were required to meet the +5.0 percent agent flowrate monitoring contractual requirement. The fill bypass system was eliminated with on-board agent volume being indicated by separate liquid level sensors in each tank. An air purge system was added to allow purging of the wing boom system after final mission dissemination.

For the final MISS agent transfer system, the recirculation line check valve was eliminated as a result of preliminary system tests, and the low volume agent strainer was moved upstream of the flowmeter to prevent foreign matter from fouling the flowmeter turbine.

(PNEUMATIC AND DUMP SYSTEMS NOT SHOWN)

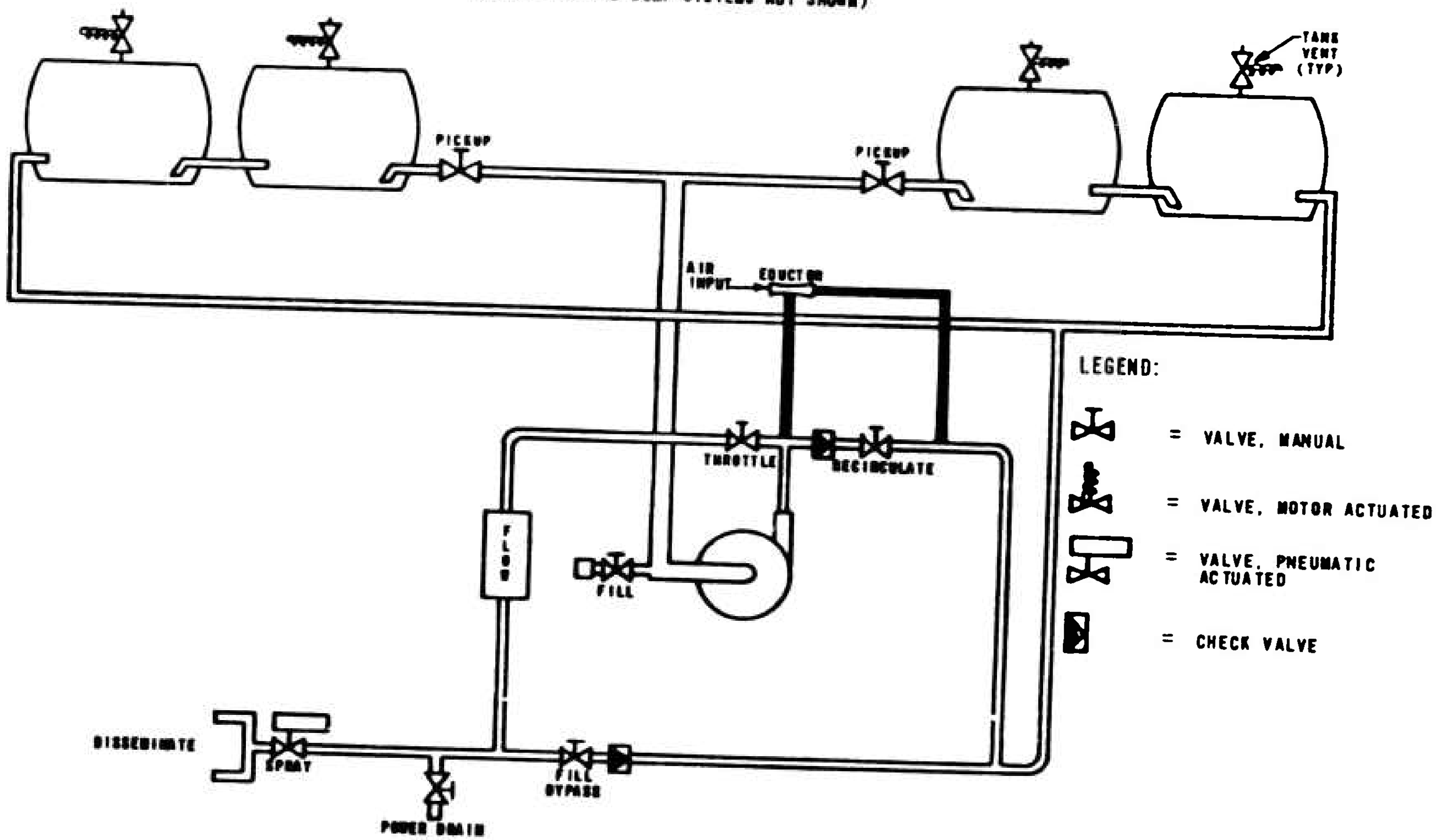


Figure 42. Agent Transfer System (Third Concept)

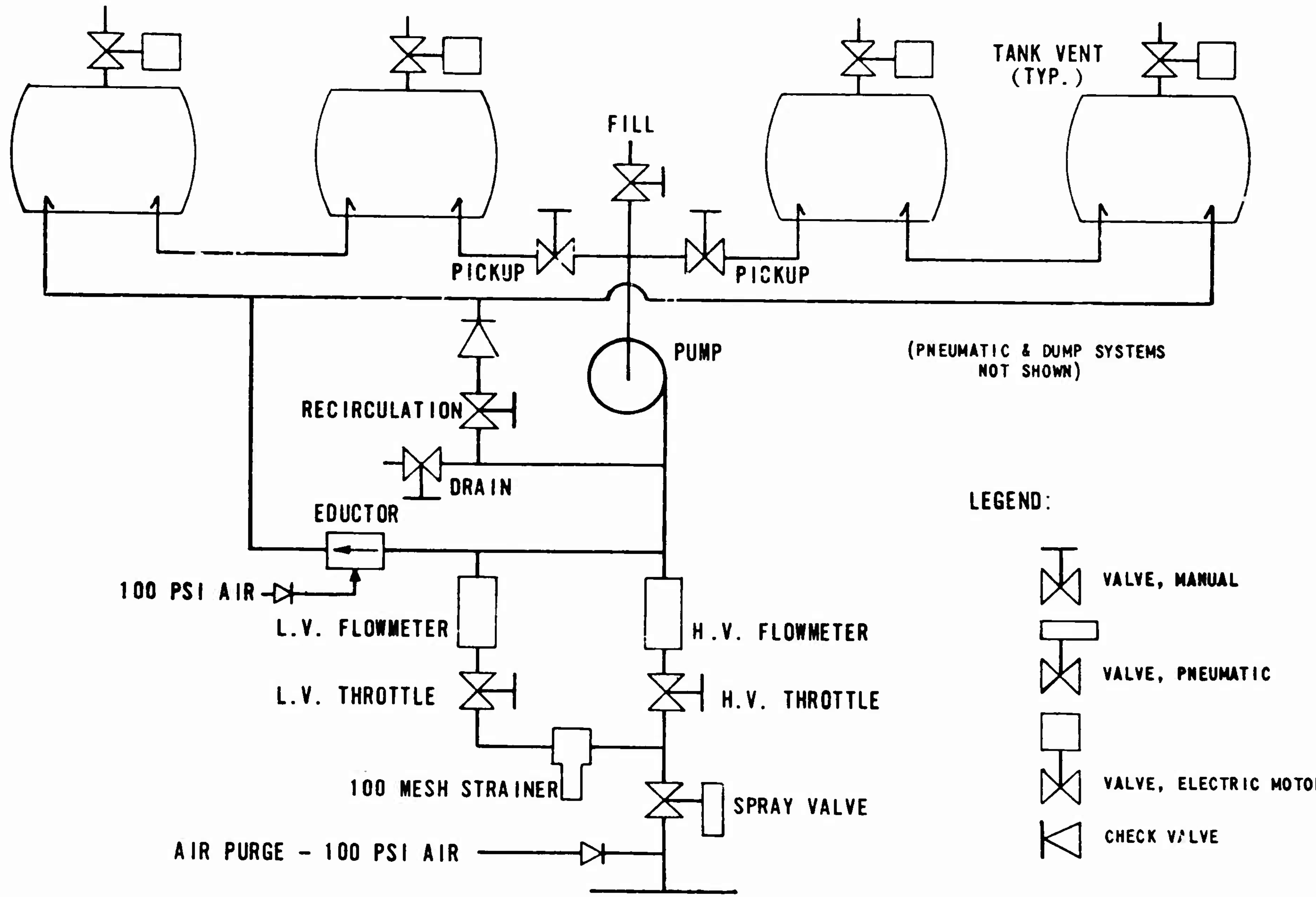


Figure 43. Agent Transfer System (Fourth Concept)

4.4 PLASTIC AGENT TRANSFER SYSTEM FLOW MODEL

To investigate all phases of operations of the multi-tank agent transfer system concepts, DTL built the one-quarter scale plastic flow model shown in Figure 44. The model utilized eight agent reservoirs and was equipped with all the piping, valving, and electrical controls required for complete system operation. The tanks had a scale volume of 325 gallons each.

Figure 45 shows the flow model schematic and controls. The following operational modes were investigated with the model level and with the model sloped to the horizontal (aircraft nose up or nose down):

- Suction filling
- Recirculation/agitation
- Dissemination with and without recirculation

4.4.1 Suction Filling

To suction fill, the pump was switched on, and the fill switch was thrown. This opened all tank solenoid vent valves and closed the pickup shutoff valves. The recirculation valve was manually opened. To prime the pump the 55-gallon drum was pressurized to 2 psig, forcing agent through the suction fill recirculation line into the reservoirs. When filling at a scaled flow rate equivalent to 350 gpm, the outermost tanks filled slightly faster than the innermost tanks. As each tank filled, its magnetic float closed the upper reed switch, closing that tank's vent valve, which prevented further filling of that tank. When all tanks were filled, the recirculation switch was thrown, opening the pickup shutoff valves, causing the system to enter the recirculation mode. The suction fill valve was then closed by hand, and the fill switch was turned off.

When filling with the model on an angle to the horizontal (such as the C-47), the lower tanks filled first due to the fluid head caused by the upper tanks. Closing the lower tanks' vent valves prevented those tanks from filling and allowed the upper tanks to continue filling.

4.4.2 Recirculation

In the recirculation mode, agent was pulled from the innermost tanks by the pump and forced into the outermost tanks. In full recirculation, the model pumped at a scale flow rate equivalent to 600 gpm, moving 300 gpm through each tank. Thus, each tank had a 90 percent volume/minute recirculation rate (300 gpm/325-gallon capacity).

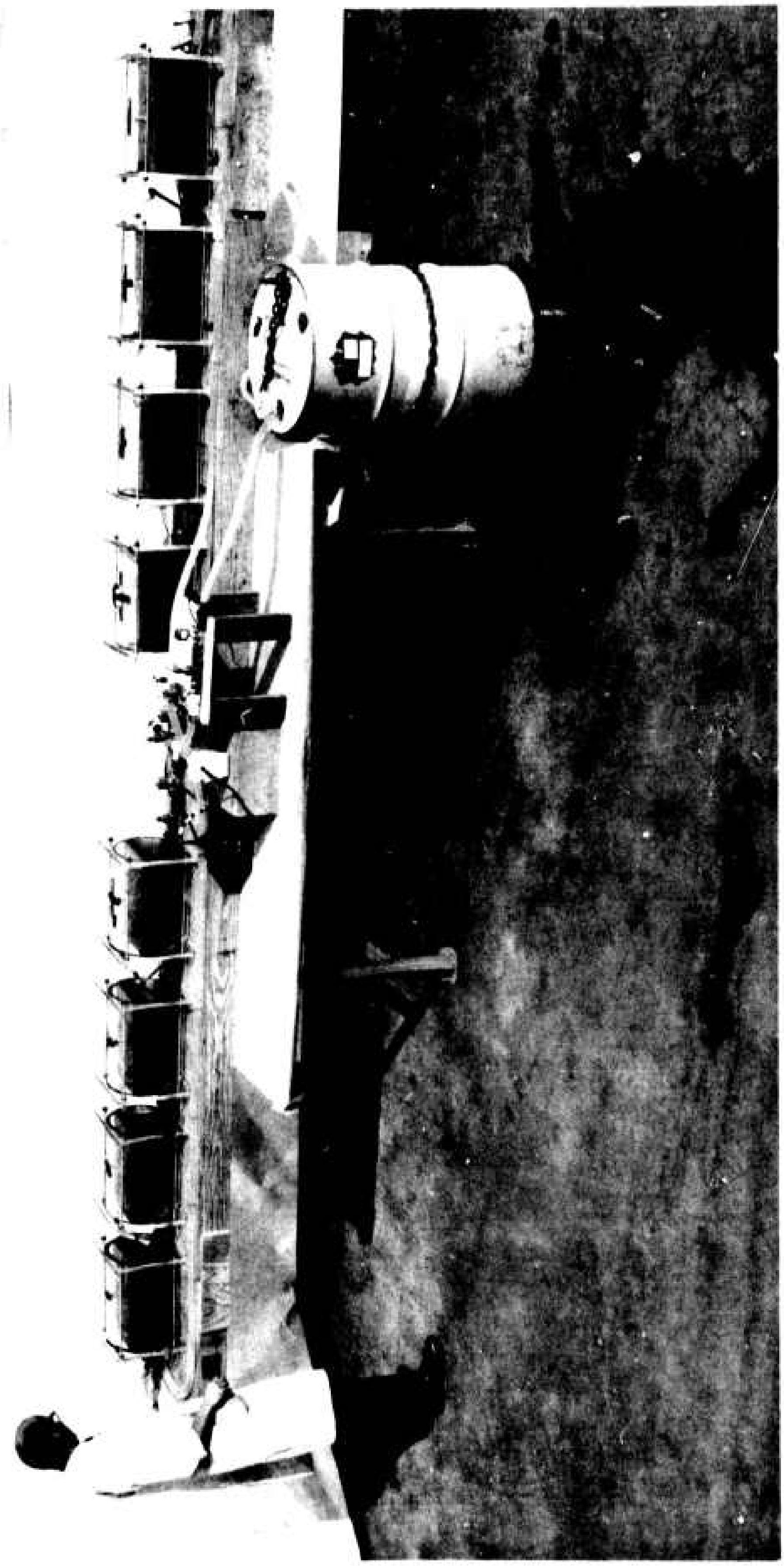


Figure 44. Plastic Agent Transfer System Flow Model

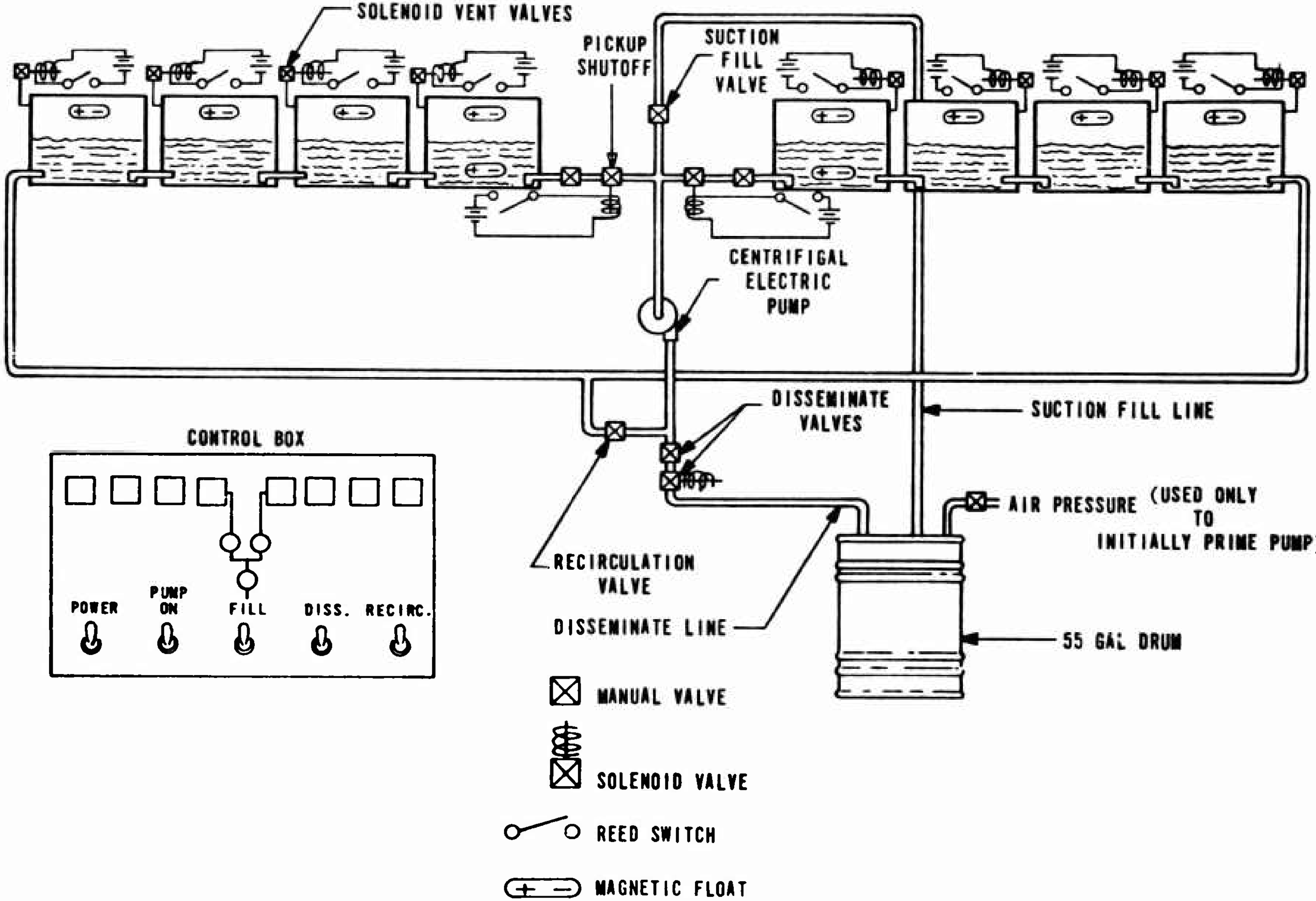


Figure 45. Plastic Flow Model Schematic

The fluid level in each tank remained constant regardless of model orientation since each tank vent was closed.

To test the mixing capability of the scaled 300 gpm through each tank, dye was introduced into one end tank. With all tanks one-half full, the dye dispensed evenly through the first four tanks within 1-1/2 minutes and through all eight tanks within five minutes. With all tanks full of fluid, the dye evenly dispersed throughout all eight tanks within nine minutes.

4.4.3 Dissemination

When the dissemination switch was thrown, the solenoid dissemination valve opened disseminating the fluid into the 55-gallon drum, and the two outermost tank solenoid vent valves opened. Various dissemination rates were tried up to a scale 600 gpm.

While disseminating, the outermost tanks emptied first, then the next outermost, etc. As the innermost tanks emptied, their pickup shutoff solenoid valves closed independently just before the pick-up tube started to suck air. This arrangement assured maximum agent would be disseminated in case the tanks were filled somewhat unevenly. When disseminating with the model on a slope to the horizontal, the upper four tanks emptied slightly sooner than the lower four tanks, but nearly all agent was disseminated due to the automatic pickup shutoff valves. This automatic pickup shut-off concept was later eliminated from the final system concept due to complexity and expense.

The dissemination process was identical with or without recirculation. When recirculating through an empty tank, the fluid passed right through the tank and did not fill it, since fluid was being withdrawn at a faster rate than it was being introduced (dissemination+recirculation>recirculation).

4.5 TANK MODULE

The modular concept of the MISS dictated that as many components and parts of the system be designed in such a manner that they could be assembled together in appropriate combinations in order that the payload capacity of each aircraft be exploited. The agent reservoir, as a primary part of the system, received the closest attention in modularizing the spray system.

First, the maximum payload capacities of the four primary and six secondary aircraft were obtained. The estimated weights of the power module, spray booms, and interconnecting plumbing were subtracted from those payload weights to obtain the estimated specific gravity of 1.0 or water at a nominal 8.34 lb/gal. If specific gravity 2.0 agent is used, the agent volume in the tank would be halved. Coincident with the weight analysis, dimensional constraints were evaluated to establish the width, height, and length of the power module and agent reservoir.

Secondly, these estimated weights and dimensional requirements were applied to the power module and agent reservoir, and various cargo compartment arrangements were made for all aircraft. It soon became apparent that the control of the aircraft center of gravity was of critical importance. The center of gravity of each aircraft had to be within very specific limits from empty to full payload capacity. Since the agents to be sprayed were liquid, constraints against its movement during aircraft flight were also to be imposed. For this reason, the original tank concept, as shown in Figure 46, was abandoned.

The approach was then taken to place the power module on the center of gravity and split the agent into two series of tanks, one set forward and one set aft of the power module. By extracting from both sets of tanks at the same rate during spraying, the aircraft center of gravity would not change from full to empty. The tanks are separate, connected only by an agent transfer tube at the tank bottom with each tank's vent being individually controlled. Closing a tank's vent prevents movement of agent into or out of the tank. This solves the problem of slosh or movement of agent between adjacent tanks.

During dissemination, only the vents on the tanks furthest from the power module are opened, allowing the tanks to empty sequentially from the outside tanks inward.

The first split series tank module concept is shown in Figure 46. The tanks had a capacity of 325 gallons each and were 42 inches in diameter. The cradle was designed with captive castors; integral dump, vent and recirculation lines; and built-in forklift slots. The tank ends included agent inlet and outlet tubes and an integral emergency dump valve. The fill port was offset to reduce the module height.

Upon further study, it was decided to change the tank capacity to 500 gallons by increasing its diameter to 48 inches. This was done to substantially decrease the number of tank modules in each aircraft installation, and thus reduce cost, parasitic hardware weight, installation time, and system complexity. The inlet and outlet ports were moved underneath the tank (Figure 48) to allow both end-to-end and side-by-side installation possibilities. The inlet and outlet tubes were curved up, over, and down inside the tank to provide maximum recirculation agitation at the tank bottom and to allow either tube to be used as the suction port.

Using the 500-gallon tank concept, the nearly finalized tank module was generated, as shown in Figure 49. Because the tanks were designed for the possibility of side-by-side installation, the integral dump, vent, and recirculation lines were removed. A completely new, lightweight cradle was designed and included captive castors, lifting jacks, and forklift slots. Eye bolts were provided for sling lifting and aircraft tie-down. An

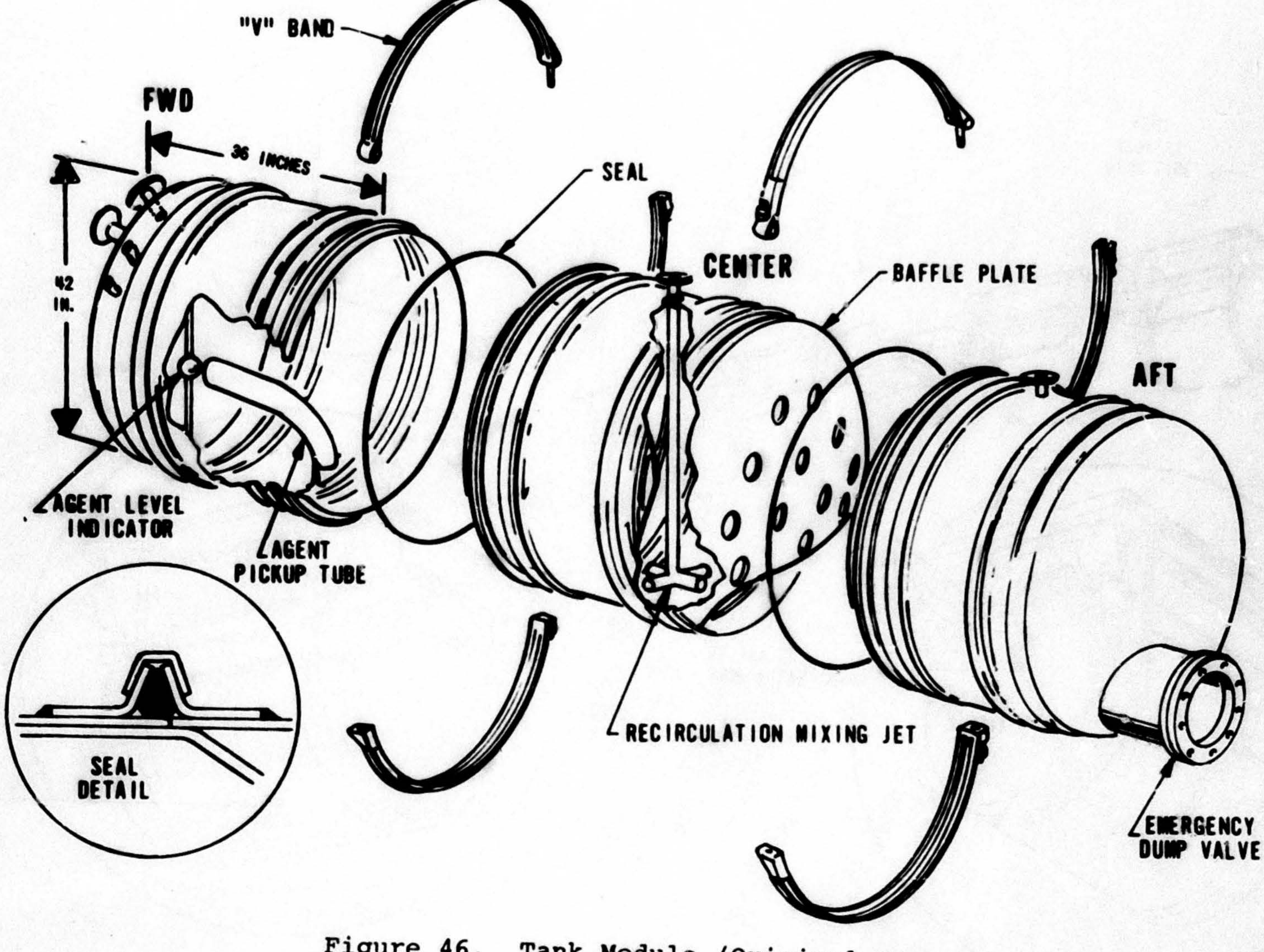


Figure 46. Tank Module (Original Concept)

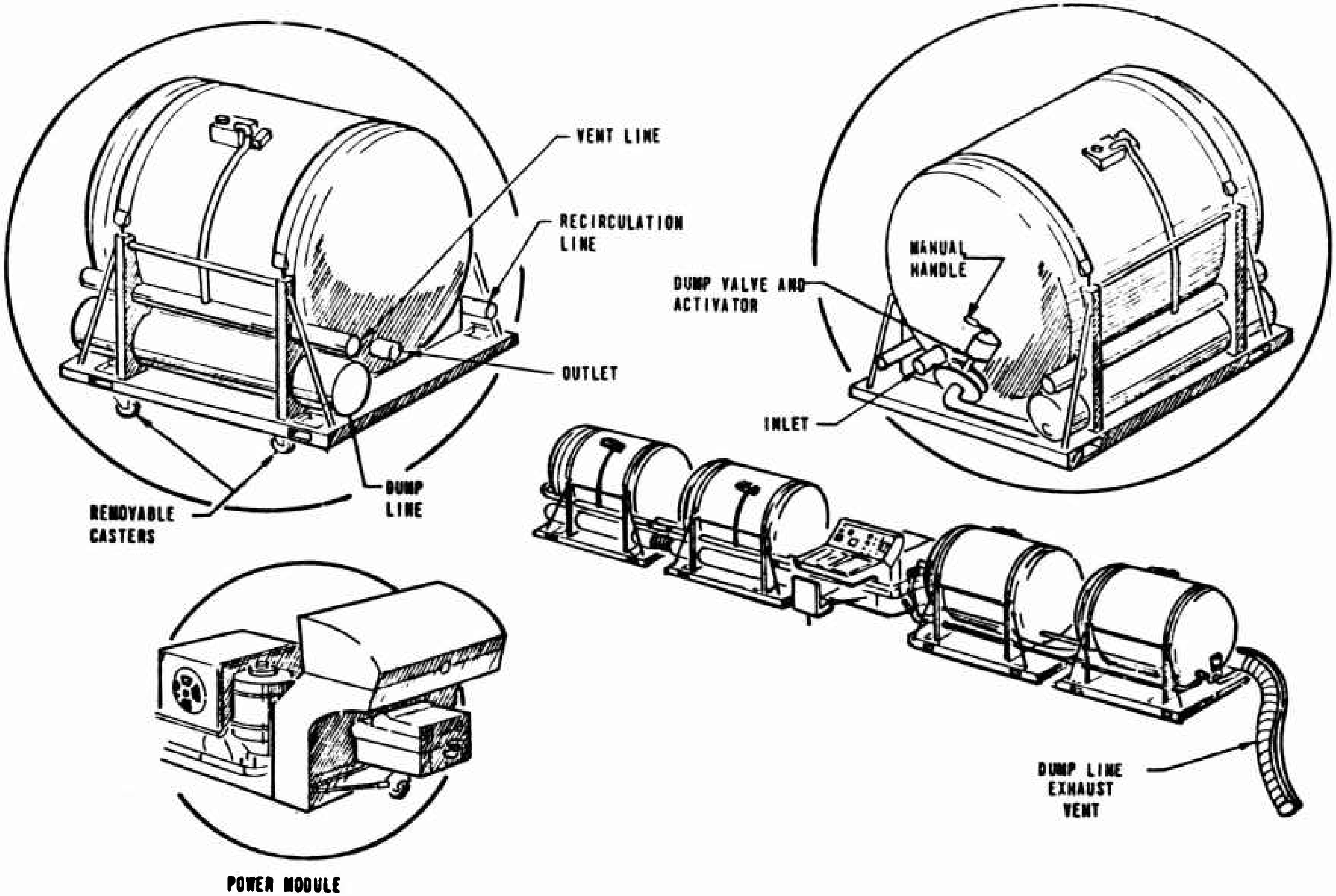


Figure 47. Split Series Tank Module (First Concept)

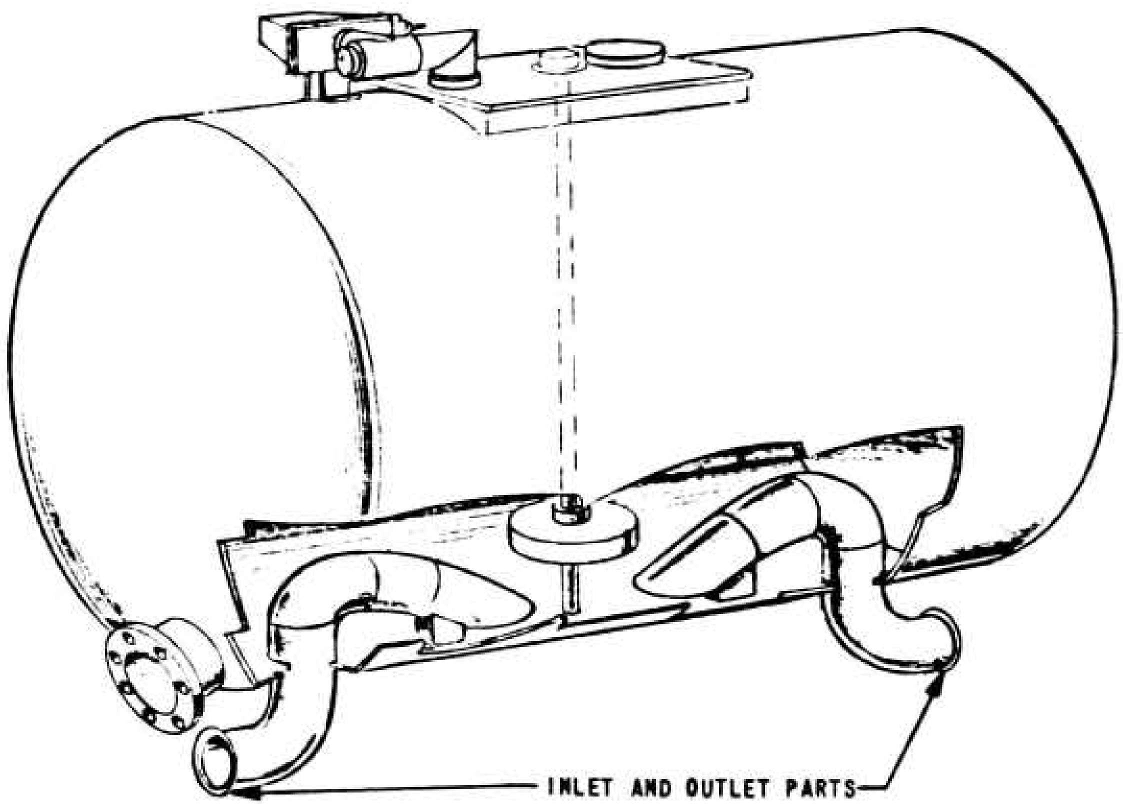


Figure 48. 500-Gallon Tank

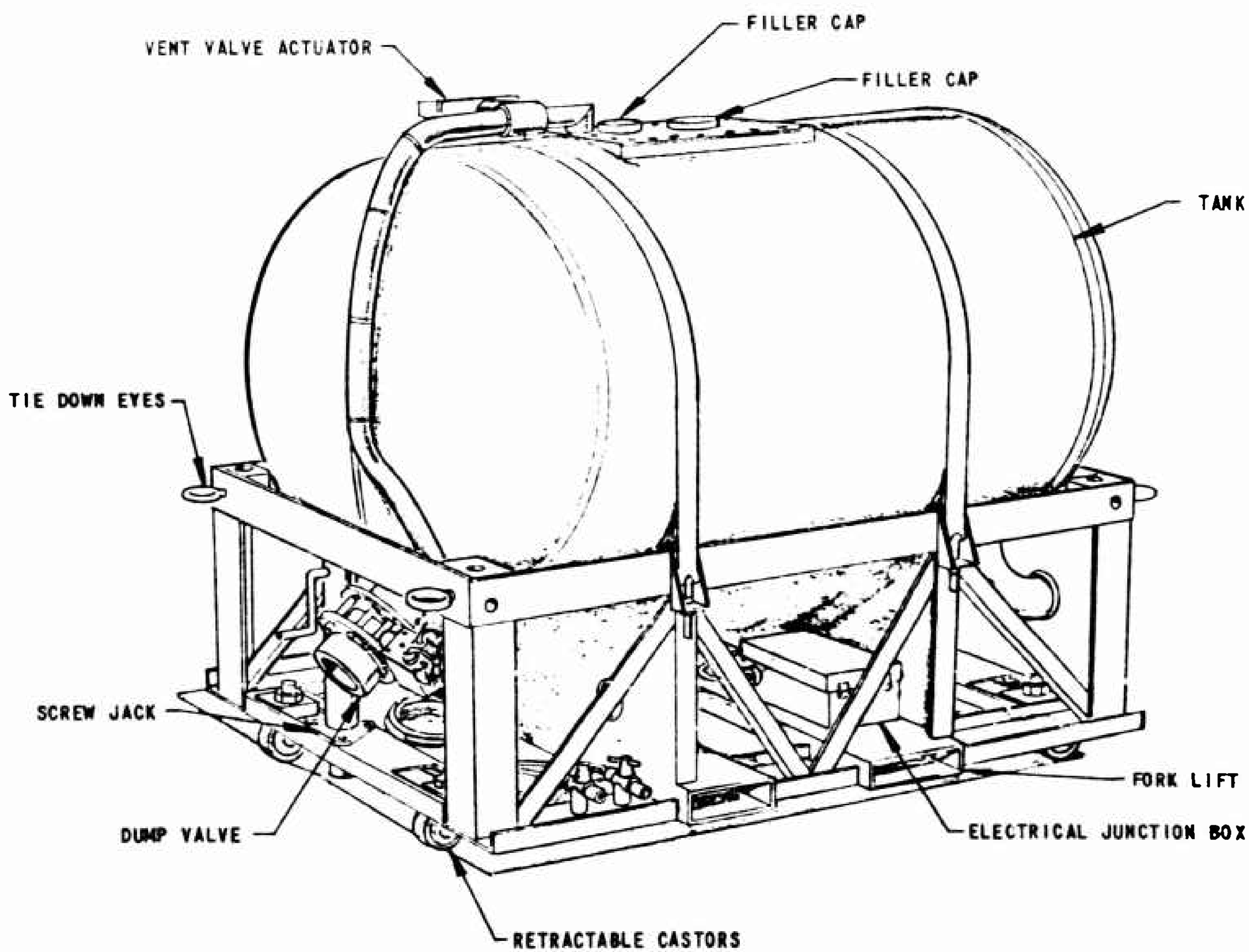


Figure 49. 500-Gallon Tank Module

electrical junction box was provided for the liquid level indicator and motor-driven vent valve electronics. Both the electrical cable and dump valve air connections were designed to allow the tanks to be connected in series to minimize wiring and air hose connecting errors and simplify installation. The tank fill port was increased in size to three inches and a screen was added to trap foreign matter if the tanks were filled through their fill ports. The fill cap, liquid level indicator, and tank vent were mounted on a manhole cover, and the manhole was sized to allow entry into the tank if desired. An internal agent slosh baffle was added which consisted of a curved, perforated sheet in the center of the tank, covering the bottom half of the tank's circular cross-section. This plate was designed to adequately control slosh at minimal cost and weight by taking advantage of the inherent strength of a curved sheet.

The final MISS tank module was the same as shown in Figure 49 except the vent line and valve were increased in size from 1 to 2 inches in diameter to decrease emergency dump time.

Detailed evaluation of reservoir and power module arrangement in each aircraft is presented in paragraph 4.1. As can be seen from Figures 15, 20, 21, 22, and 23 of paragraph 4.1, slight variances from the concept of symmetrical tanks around the power module were necessary to insure compatibility with all aircraft.

4.6 POWER MODULE

The power module must contain plumbing, valving, electrical diagnostic equipment and controls, and a power source and must be designed to mate with all aircraft configurations and meet floor-loading requirements. During the design and development effort, consideration was given to ease of operation, accessibility of components, balancing of fluid paths, and weight and safety requirements.

Several preliminary and subsequent designs of the power module were made to incorporate the various system changes. One early design is shown in Figure 50 and incorporated the PE90-7 engine which was also used on the final design. It had an electromagnetic induction flowmeter which was later eliminated in favor of dual turbine-type flowmeters. Captive castors and lifting jacks were incorporated to simplify aircraft installation and removal. The operator seat was attached to the power module, with the control console located as shown.

The power module, which is almost finalized, is shown in Figure 51. This module was designed by taking all necessary components and generating several sketches of different plumbing positioning concepts. The most functional design was selected, and the actual hardware assembly was fabricated. During fabrication, the cradle was simultaneously designed and fabricated to adequately support the various components. All controls were positioned within easy

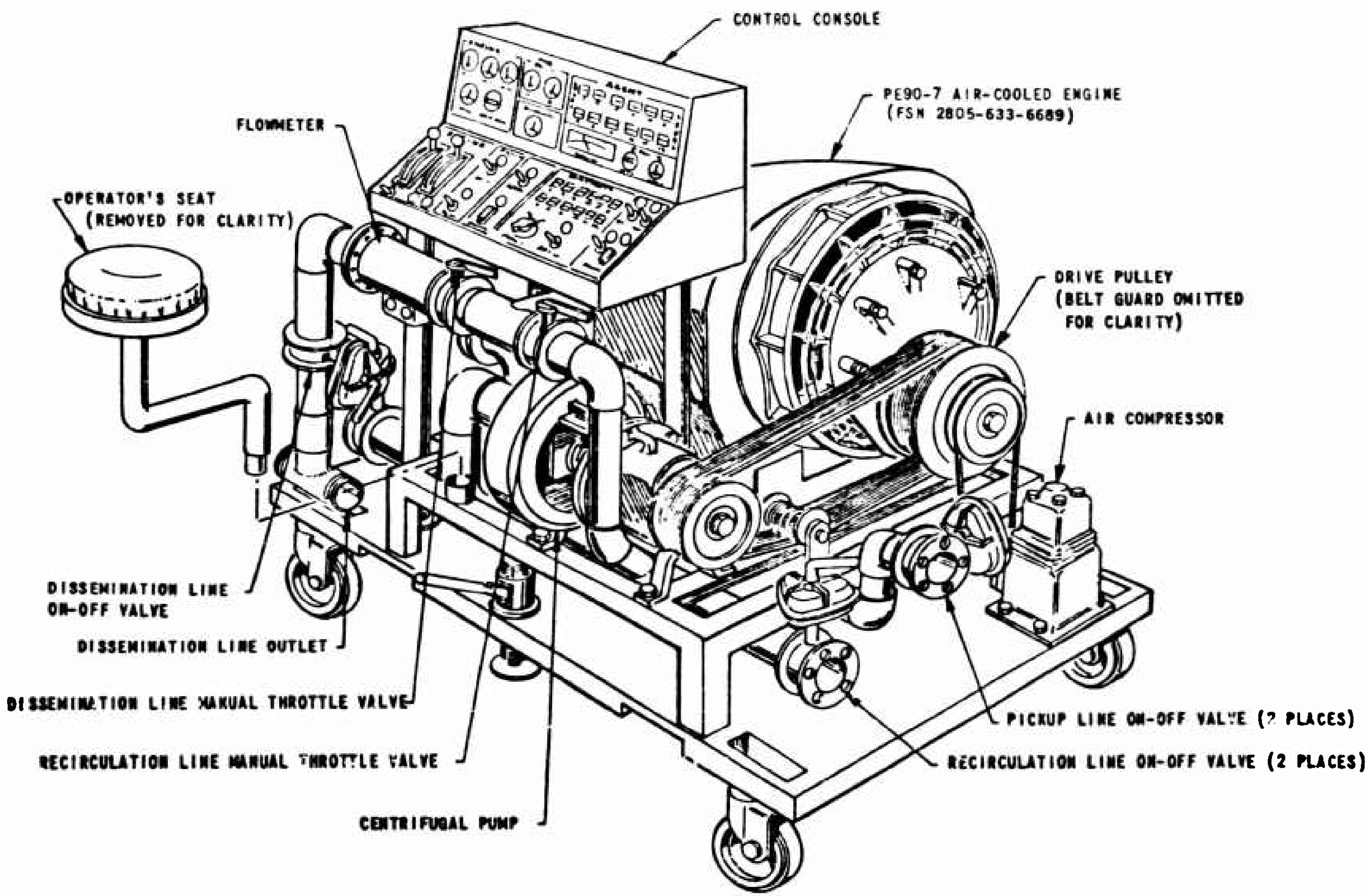


Figure 50. Power Module (Early Design)

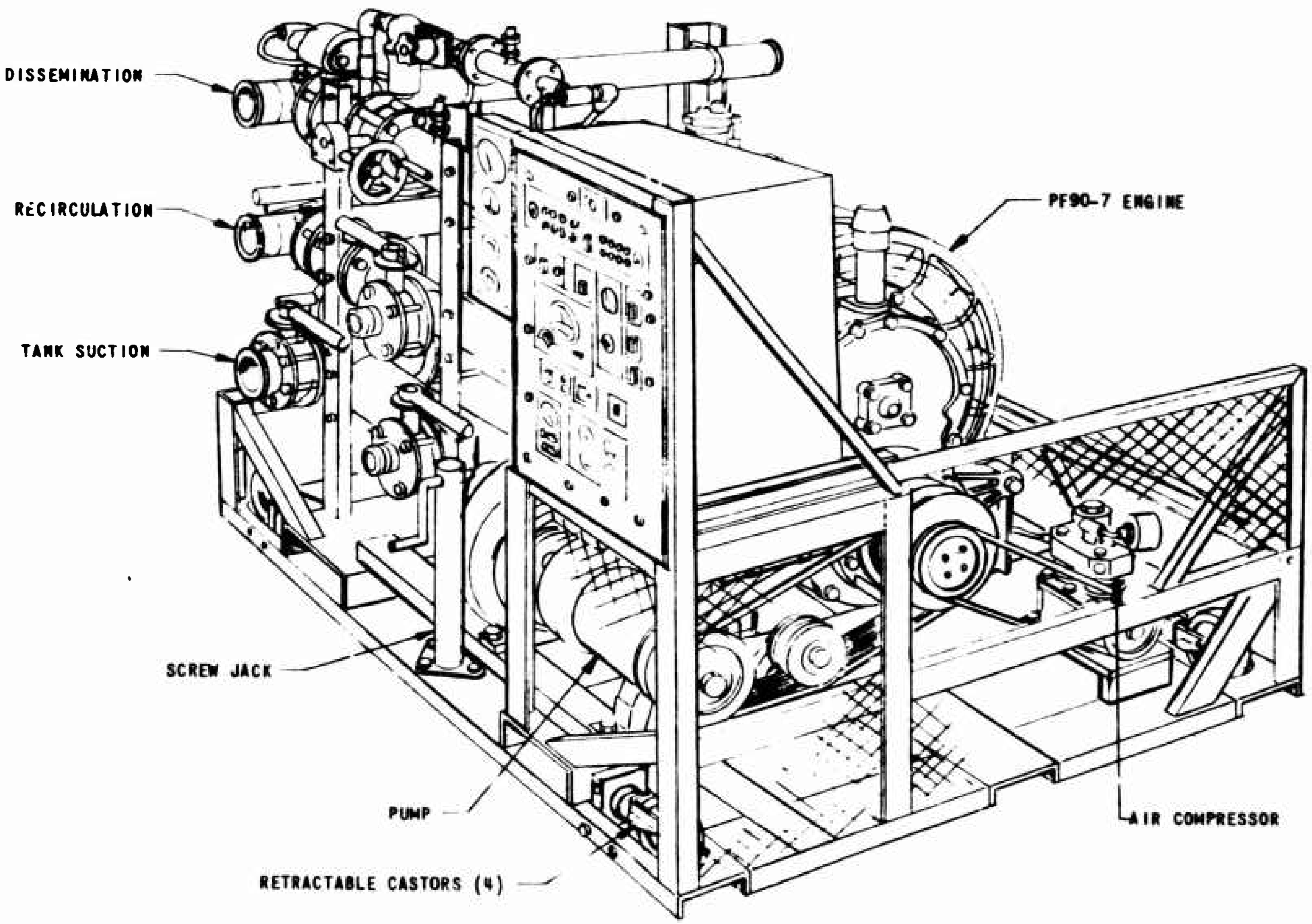


Figure 51. Power Module (Later Concept)

reach of the operator, and the operator seat was designed to be positioned in front of, and separately tied down from, the power module. The control box was designed with a hinged panel to permit easy access to the control box components.

The final MISS power module design (see Figures 5, 6, 7 and 8 in Section III of this report) included some minor cradle and plumbing changes. The lower cradle channels were inverted to provide better aircraft floor loading, angled corner cradle supports were replaced with gussets, an idler pully was added to the air compressor drive belt, and the system battery and emergency dump air reservoir were added to a structure behind and above the control box. A circuit breaker box was added below the main control panel, and a second primary air reservoir was added underneath the pump drive train.

4.7 INTERNAL PLUMBING

The MISS internal plumbing includes the tanks/power module agent hoses, the dump, vent, and engine exhaust systems, and the internal dissemination hoses and hardware. Laboratory agent compatibility tests were conducted on agent hoses to determine acceptable materials (see paragraph 4.2 of this report). For actual locations of internal plumbing on the various aircraft, see the respective aircraft Class II modification documentation.

4.7.1 Agent Hoses

Two types of agent hoses are required: High pressure hose used for agent dissemination and recirculation, and suction hose used to connect between the tanks and to connect the power module to the inside tanks. These hoses must be compatible with all MISS agents. In addition, the hose must be flexible enough to allow connection at the desired points.

As a result of preliminary laboratory chemical agent compatibility testing, Teflon®- or nylon-lined hoses were determined to be acceptable. A survey of available hoses indicated that nylon-lined hoses were not manufactured to meet the MISS requirements, and Teflon® hoses were extremely costly. Further research indicated that a cross-linked polyethylene-lined hose was available to meet the 100 psi high pressure hose requirement. Although extremely stiff, this hose was selected to reduce costs without sacrificing system performance. A Teflon®-lined duct was selected for suction line applications, and the system was designed accordingly.

The cross-linked polyethylene-lined hose worked perfectly during the remainder of the program, but the Teflon®-lined suction duct exhibited both leakage at the Teflon® liner seam and suction collapse of the liner. After several attempts by the manufacturer

to correct these problems, they discontinued their effort and agreed that their product was misrepresented and should not be used for fluid service.

The failure of the suction duct created a problem because it was extremely flexible and the suction portion of the system had been designed around this duct flexibility. The resulting search indicated that no hoses were available to meet the chemical compatibility requirements, match the duct flexibility, and be relatively inexpensive. As an interim solution, vinyl hoses were provided on the prototype system. Vinyl is not compatible with all agents but sufficed for Air Force system flight testing using glycerin and water as an agent simulant. An all Teflon® hose was located which met the compatibility and flexibility requirements, but was extremely expensive and lacked good sealing at the end fittings. The final solution to the problem was an all stainless steel bellows hose with the end flanges welded on. This hose was then specified for all MISS suction hose applications.

4.7.2 Internal Dissemination Hardware

High wing aircraft had to use two fuselage hose assemblies to feed the separate wing boom assemblies, and it was decided to design the spray system to include fuselage spray stations at the jump doors. For lower performance aircraft such as the C-123, this was accomplished by constructing a stainless steel tee which was bolted to the cargo floor using existing cargo tie-down points. This tee was designed to accept the single 3-inch-diameter dissemination hose from the power module and distribute the agent to the twin fuselage hose assemblies.

At the point of attachment of the fuselage hose assemblies, nozzle spray stations were incorporated. For high performance aircraft such as the C-130, twin 3-inch hose dissemination lines from the power module were connected to individual elbows which subsequently fed the fuselage hose assemblies and the fuselage spray stations.

For low wing, low performance aircraft such as the C-47, a single 2-inch dissemination line was run from the power module, out through the side cargo door, under the fuselage, and connected directly to the wing boom system. Since nozzle stations were placed uniformly along the wing boom system, including under the fuselage, fuselage spray stations were not required.

4.7.3 Dump System

The dump system was originally conceived as exhausting through the aircraft rear jump door to eliminate metal-cutting operations. The use of modular tanks which could be installed in various configurations then dictated that the dump system also be modular. To achieve this, a 10-inch-diameter silicone-coated glass duct was selected for the main dump duct which has sufficient capacity to accept four tank module 4-inch-diameter dump ducts. A 12-inch

modular length was selected for the 10-inch duct, and connections were made to the 4-inch-diameter tank dump ports with stainless steel tees and band clamps. A dump chute was located at the jump door which projected about 12 inches into the windstream to minimize dump contamination of fuselage. This dump chute was beveled at 45° facing aft to allow the windstream to create a slight vacuum condition in the dump line and thus reduce dump time. The dump chute was designed to be mounted with a plate, which was bonded to the aircraft floor with silicone adhesive.

4.7.4 Vent System

The vent system consists of modular lengths of a main 3-inch-diameter silicone-coated glass duct attached to the 2-inch-diameter tank vent ducts with stainless steel tees and band clamps. The tank vent hoses and vent valves were originally designed as 1-inch diameter but were later changed to 2-inch diameter to decrease dump time. A vent chute was utilized in the aft jump door which projected into the airstream. This vent chute was chamfered 30° facing forward to allow slight ram air pressurization of the tanks to decrease emergency dump time.

4.7.5 Engine Exhaust

The engine exhaust was ducted from the engine spray arrestor to the exhaust chute at the aft jump door using 3-inch-diameter silicone-coated glass duct. Due to the Air Force objection to the silicone glass duct, it was replaced with asbestos-packed stainless steel exhaust hose. For certain aircraft such as the C-123, the exhaust hose was secured to the overhead paneling using mounting brackets, bonded to the aircraft with silicone adhesive. For other aircraft, the exhaust hose was secured to existing aircraft internal structure using standard hose brackets and band clamps.

4.8 EXTERNAL PLUMBING

Aircraft external plumbing includes the nozzles and nozzle valves, wing boom system and fuselage hose assemblies. Complete descriptions and installation instructions for the various aircraft MISS installation wing boom systems can be found in the applicable aircraft Class II modification documentation. During the MISS program, Class II modification documentation packages were generated for the C-47, C-123, and C-130 aircraft.

4.8.1 Nozzles and Nozzle Valves

The original nozzle/nozzle valve approach is shown in Figure 52 and used a spring-check valve method of sealing the nozzle when dissemination was terminated. The nozzle and valve were custom-fabricated parts. This concept was abandoned when further investigation of the sealing pressure requirements at the nozzle valve

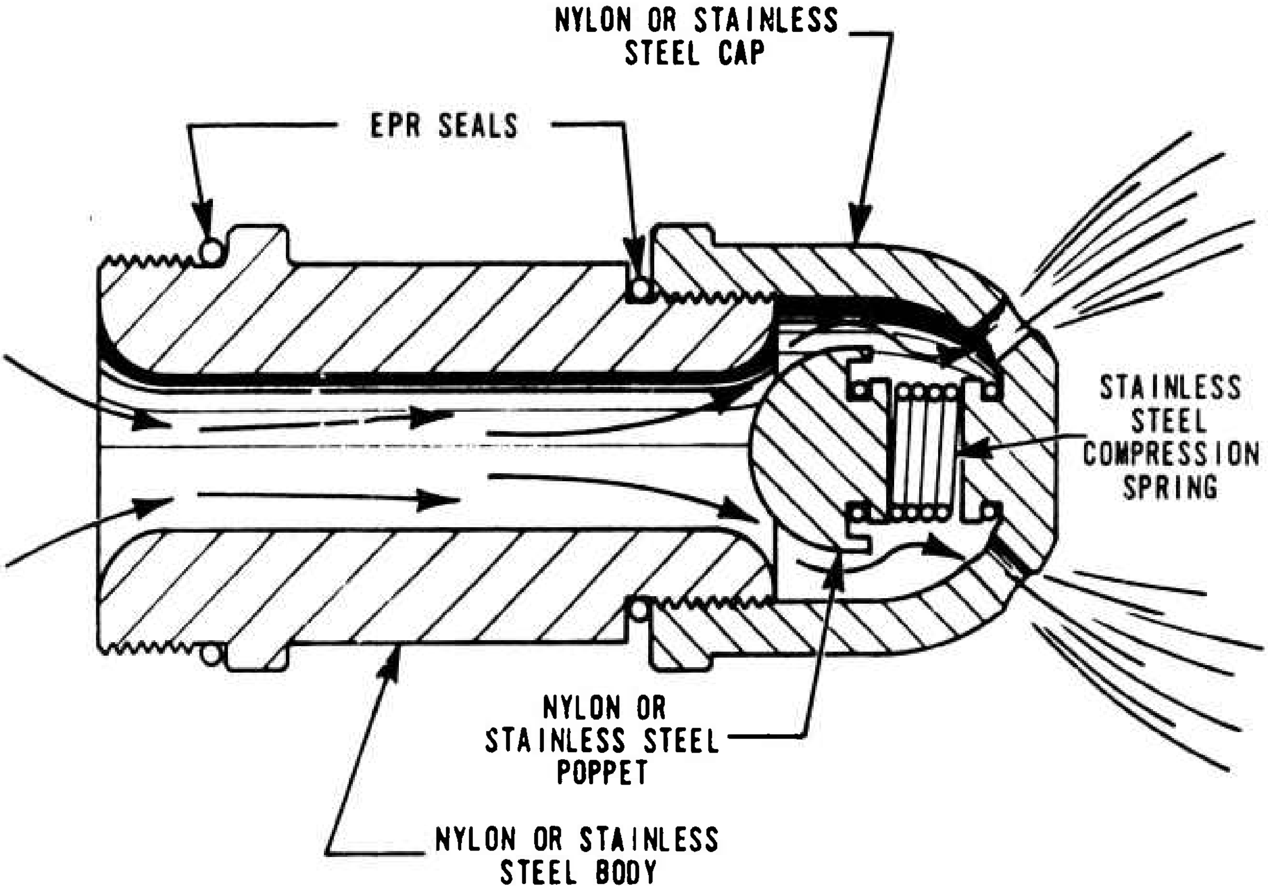


Figure 52. Check Valve-Type Nozzle

indicated that a spring-check valve could not seal against agent pressures generated within the wing boom when certain larger aircraft saw maximum lateral airborne g-loadings. In addition, the custom nozzle approach was expensive and did not comply with the concept of using readily available hardware when possible.

Research of standard valves revealed that an inexpensive, small diaphragm check valve was available (Figure 53). The checking function of the valve was increased by supplying compressed air behind the diaphragm at all times except during spraying. When air pressure is not available, such as during aircraft downtime, the check valve spring will continue to seal up to 5-psig agent pressure to prevent leakage at the airfield. The valve is fail safe in that it will allow spraying even if the air source fails. In addition, the inherent design of the valve prevents "water hammer" in the dissemination plumbing. After testing and rejecting Teflon® and silicone, a fluorosilicone diaphragm was added to the agent side of the standard fairprene diaphragm to insure chemical compatibility with the agents. (See Category I Reliability Test Reports in Appendix II of this report.) The complete nozzle valve assembly was successfully cycled through a 5-year life during Category I testing, and the ability of the valve to prevent water hammer was also demonstrated successfully.

Standard, inexpensive, and readily available vee-type stainless steel nozzles were selected for use with the diaphragm check valves. For optimum droplet size control, different nozzles are required for different spray rate ranges.

4.8.2 Wing Boom System

Several wing boom constructions were considered: Round, elliptical, full aerodynamic fairing, and aft fairing. The round pipe design was considered to create too much drag. The elliptical was more streamlined but presented end connection and mounting difficulties. The full aerodynamic fairing was optimum from a drag standpoint but required costly fabrication techniques. The aft fairing design was selected as being the best tradeoff between drag, cost, and complexity, and the nozzle valve nylon air line was routed through the aft wing boom fairing.

Modular wing boom lengths of 8 feet and approximately 4 feet, with nozzle stations spaced every 2 feet (2 each on 4-foot boom, 4 each on 8-foot boom), were selected from preliminary layouts of the wing boom system on all applicable aircraft. Flow rates for the larger aircraft, such as the C-130, dictated the 2-inch-diameter wing boom agent pipe. The C-123 required special wing boom sections to pass under the nacelle fuel tanks and were equipped with a spray station located on the nacelle centerline to try and fill in the spray pattern void created by the propellers. The C-130 system used special heat-resistant, 4-foot boom sections behind the engines which were manufactured without nozzle stations and used copper air line in place of the standard nylon.

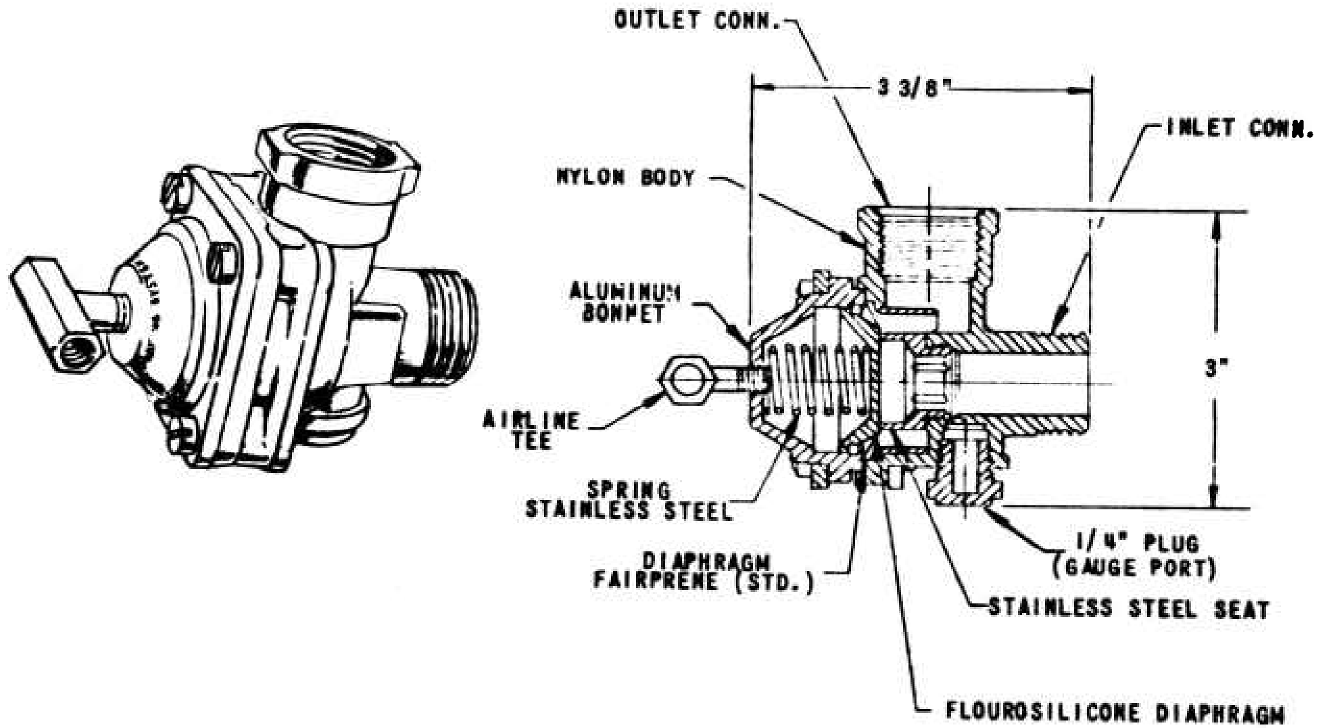


Figure 53. Nozzle Valve Assembly

At first the wing boom end connections were the non-flexible tubing type, but analysis of the larger aircraft indicated that a rigid wing boom system would not be compatible with aircraft wing flexure during flight. As a result, a flex-type wing boom system, as shown in Figure 54, was designed. Wing boom connections allowed axial flexing as shown but prevented axial rotation and end movement. The wing boom strut bolts were positioned to allow the struts to sway during wing flexure, and an inboard brace was added to prevent side movement of the wing boom. The C-123 nacelle wing boom sections were equipped with slip joints to allow the fuel nacelles to be jettisoned, and the boom air line was equipped with quick-disconnects which actuated after the boom began to separate. Silicone O-rings were added to protect the connector seals from the agents since the standard seals were not compatible with all agents.

Contractor testing of the wing boom systems for the C-47, C-123, and C-130 indicated that the wing boom self-restrained connectors do not restrain over 100-psi pressure when used with stainless steel pipe, although they are rated for 150-psi working pressure. Also, the connector seals are not adequately protected from the agents with the added silicone O-ring, and fluorosilicone seals cannot be used for self-restrained type connectors. As a result, it is recommended that the self-restrained connectors be replaced with non-self-restrained connectors of the same type (allow boom flexure), fluorosilicone gaskets be used for complete agent compatibility, and the restraining function be accomplished with external mechanical ties.

Three different wing boom brackets were designed to allow attachment of the struts. One was designed to mate with the airfoil portions of the wing boom (Figure 55). This design was vulnerable to overtorquing the nut and deforming the curved tab at the rear of the bracket. As a result, a two-piece bracket was designed which bolted together at both the front and rear. Another bracket was designed to attach to the boom connectors, and the third bracket to attach to the wing boom pipe at the nozzle stations. Both of these designs used band clamps for attachment. The three bracket types were required to allow variable positioning of the bonded mounting plates bonded to the wing surface.

A telescoping strut was designed to allow complete installation flexibility. The strut uses a band clamp to fix its length during system installation and is subsequently riveted after the entire wing boom assembly is installed. The telescoping strut was originally aluminum but was changed to stainless steel to increase strength and chemical agent resistance.

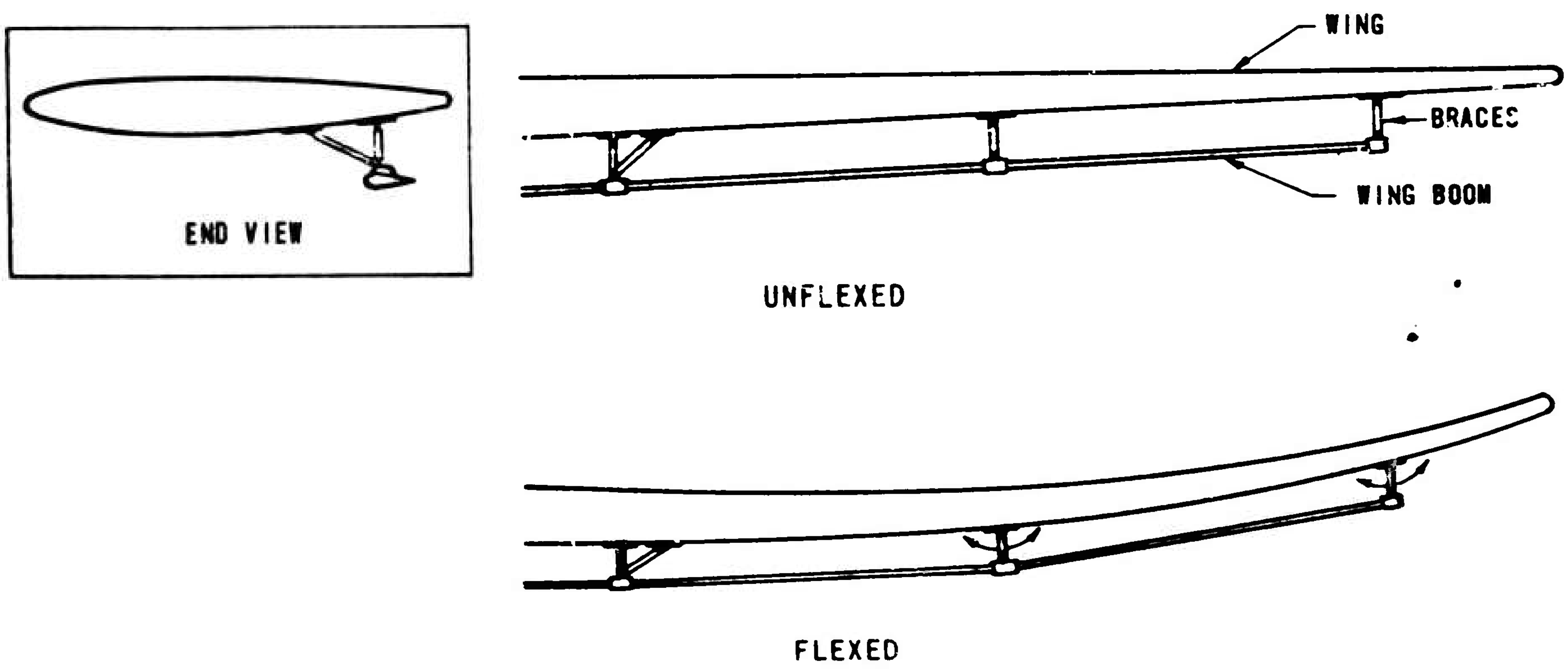


Figure 54. Dynamic Wing Boom Operation

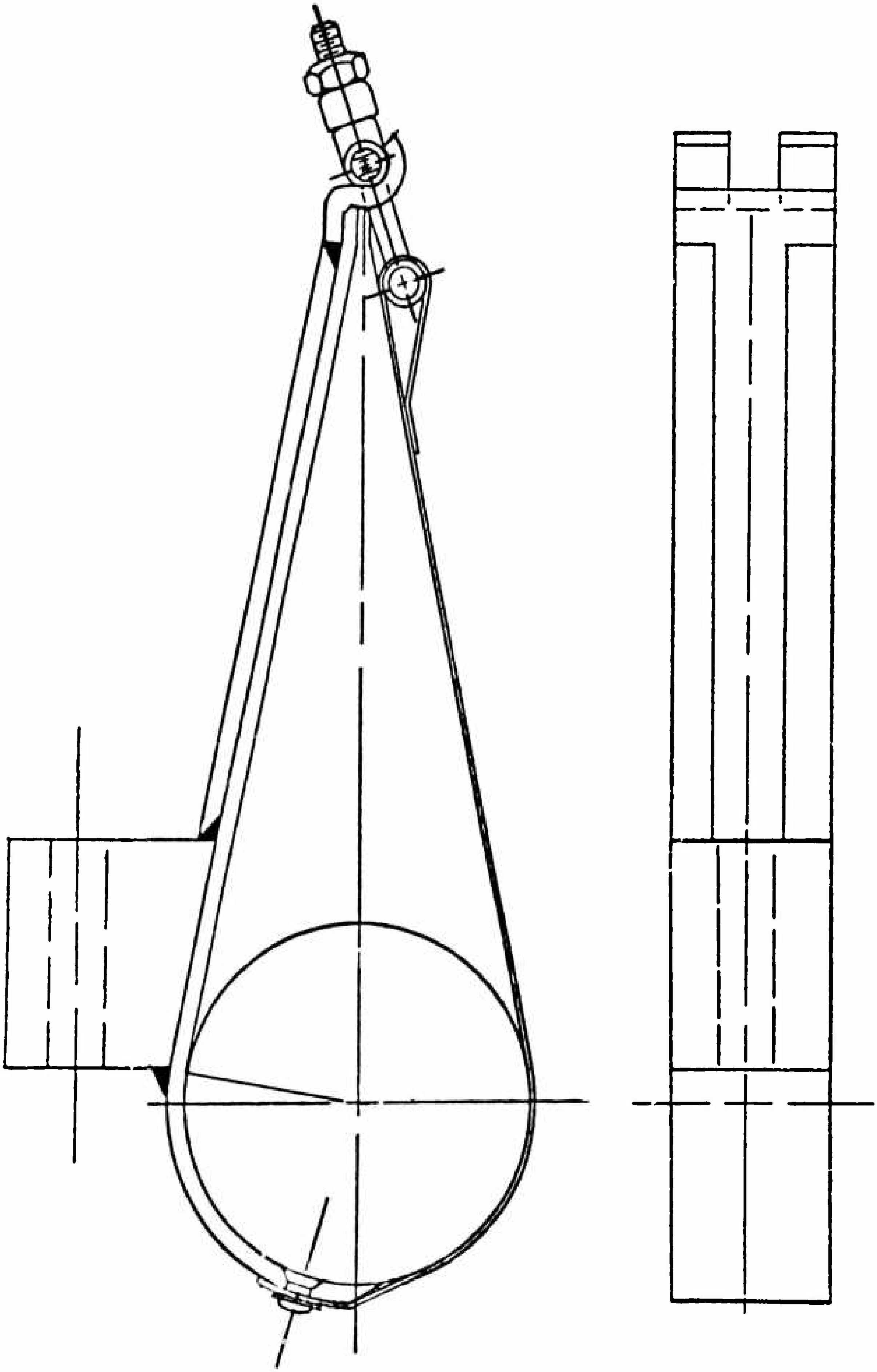


Figure 55. Wing Boom Strap Assembly

4.8.3 Fuselage Hose Assemblies

The fuselage hose assemblies consist of the same type of high pressure hose as used for internal plumbing and include an external air line to supply compressed air to the nozzle valves. The hose assemblies are attached to brackets which are bonded to the fuselage skin with silicone adhesive.

4.9 ELECTRICAL SYSTEM

The design of the electrical system was finalized after the agent transfer system design was completed. The foremost design objective was to keep the system as simple as possible and thus make it easy to understand, check out, and repair. Because the MISS may be used in remote areas and foreign countries, the electrical system was designed so that it can be completely diagnosed with a volt-ohm meter. These design criteria ruled out the use of sophisticated solid state electronics; the MISS uses conventional relays for all logic circuitry. The use of relays required more wiring, but the additional wiring expense was justified to keep the circuitry uncomplicated.

All electrical system relays, switches, and indicator lights are a single type to reduce logistics. Every individual electrical circuit is protected by its own circuit breaker. All circuitry was positioned for easy access and replacement, and each individual wire in the system is coded to correspond to the system wiring diagram.

4.10 GROUND OPERATIONS

Ground operations may be defined to include the following:

- Fill the agent tanks from 55-gallon drums, open agent containers, or tanker trucks.
- Drain the system into above containers.
- Flush the system, including tanks.
- Wash down the aircraft if contaminated.

During the development effort, it became apparent that the centrifugal pump, used in the MISS agent transfer system, could be used as the power source for all ground operations and simultaneously reduce the quantity of ground-based support equipment. A self-priming pump could have been used, but it would have required hand priming when the system was completely dry, and it would have weighed more than the non-self-priming type pumps. It became apparent that the air supply, already on the power module, could be used to actuate a pneumatic eductor, which, in turn,

would create a vacuum condition in the centrifugal pump. By attaching a ground suction hose to the suction side of the pump, the eductor could be turned off and the centrifugal pump would continue to fill the system. To prevent overfilling the tanks, each tank was equipped with a level switch which would close its vent valves when the tank was filled. When all tanks in a given system are filled, the engine magneto is shorted to prevent over-pressurization of the tanks. Turning off the fill switch allows the engine to be restarted for recirculation and/or spraying.

Figure 56 shows an operator filling the system from 55-gallon drums using the drum suction probe connected to the suction fill hose. The drum suction probe is equipped with a valve which is shut off when transferring the probe from one drum to another. Closing this suction probe valve will cause the centrifugal pump to cavitate but will not cause pump damage if closed for short periods of time. Figure 57 shows ground filling directly from a tanker truck.

Filling the MISS with wettable powder-type agents can be accomplished by filling the system as explained above with the liquid carrier agent and introducing the powdered agent directly into the tanks through the 3-inch fill caps. Mixing the agent can be accomplished by placing the system in the recirculation mode. If the powdered agent is toxic, it can be mixed remotely using a spare tank and power module, as shown in Figure 58, and pumped onboard using the ground power module.

Draining is accomplished by attaching the ground support hose to the power drain connection on the power module and using the onboard centrifugal pump to draw agent from the tanks and pump it into the ground agent containers.

System flushing is accomplished by suction filling with flushing agent and operating the system in the recirculation mode. To minimize the amount of flushing agent needed, a tank washing probe is supplied (Figure 59). This probe is attached with a hose to the power drain connection on the power module and moved from tank to tank as required.

Aircraft washing is accomplished with a trigger-operated washing gun, attached with up to 100 feet of hose to the power drain connection. The gun is a variable spray-type, allowing the operator to select a cone spray, solid stream, or complete shut-off as desired.

All hose/probe/washing gun connections are the quick-disconnect type to provide leak-tight connections with minimal effort.

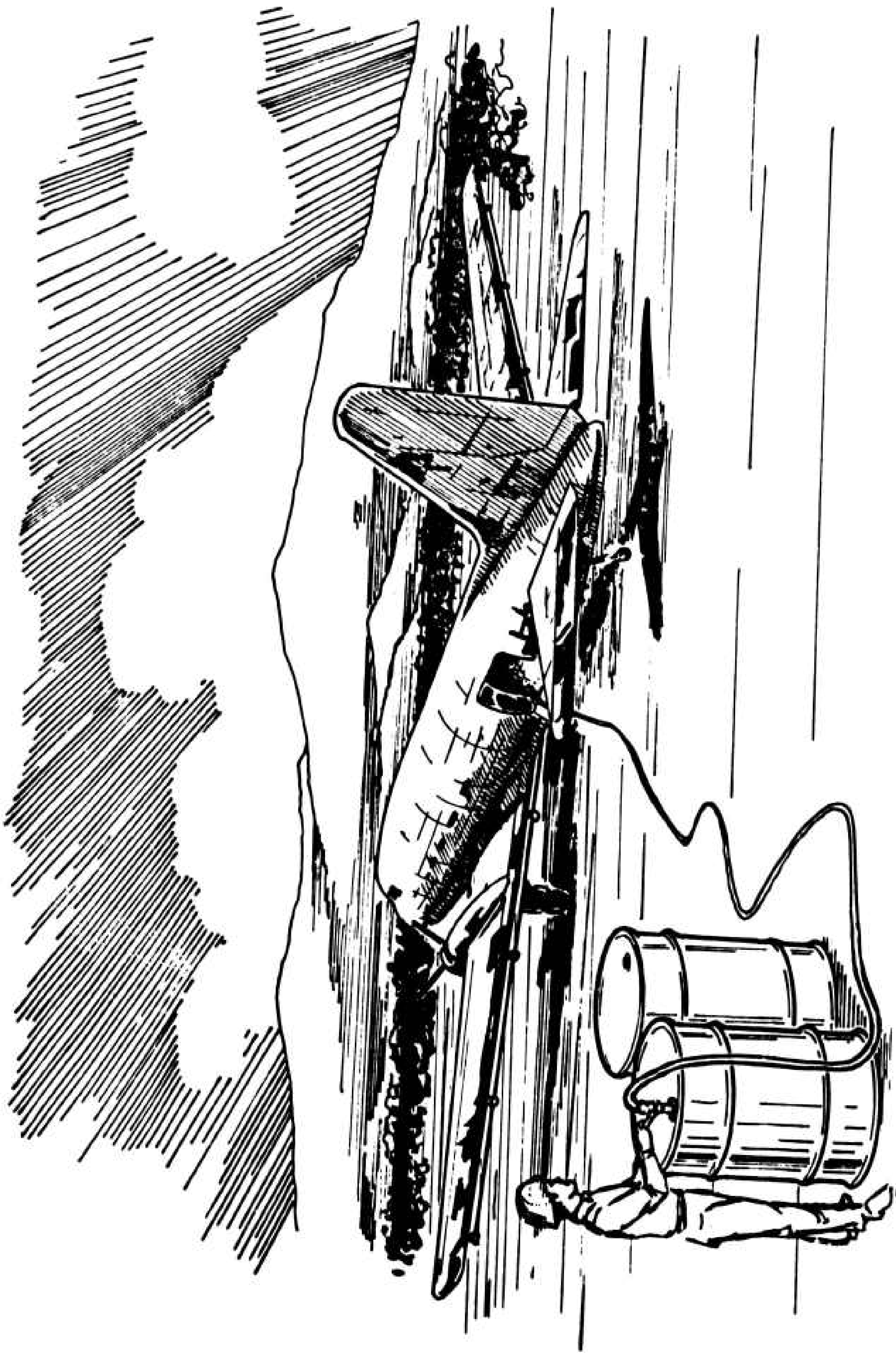


Figure 56. Field Fill

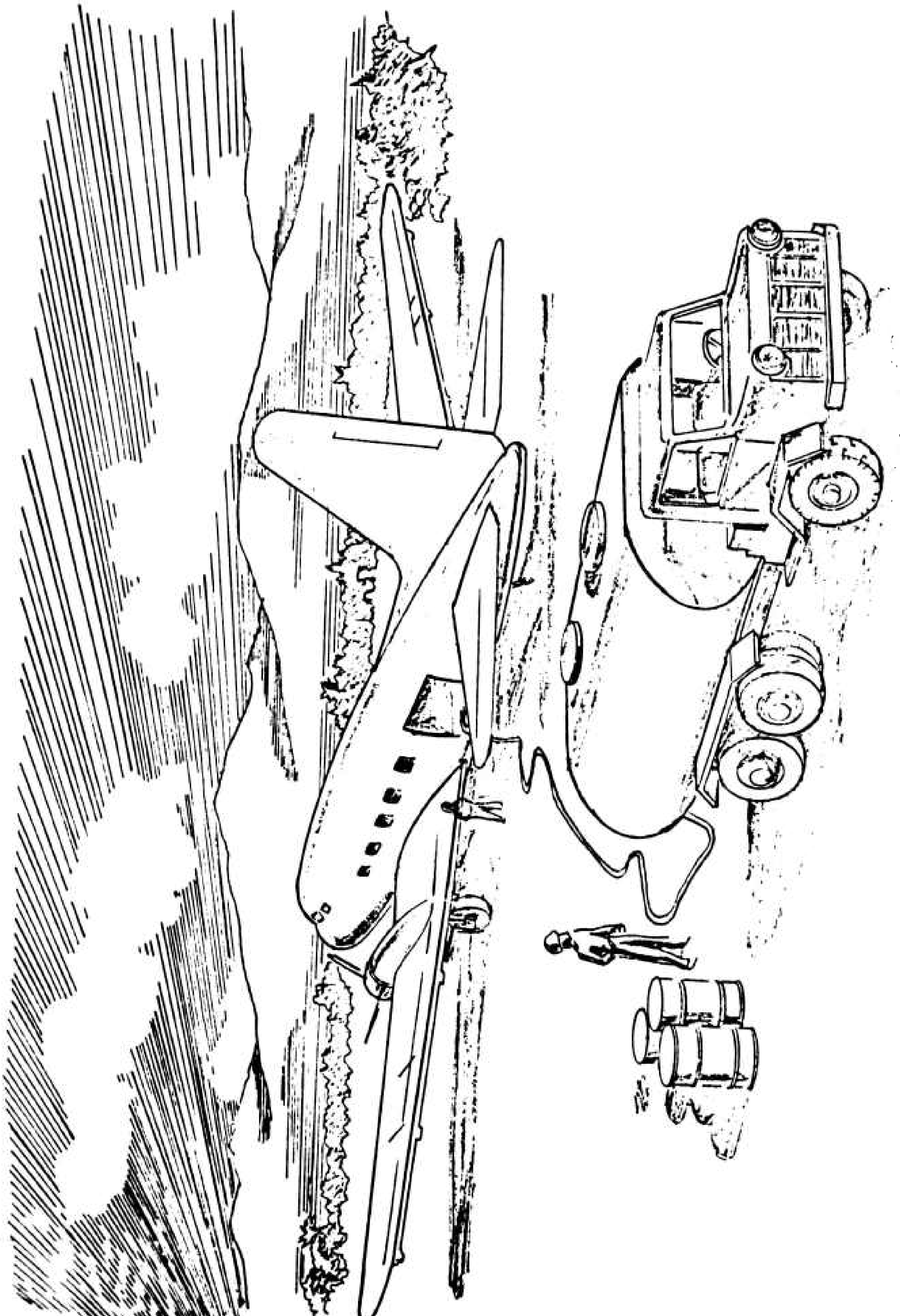


Figure 57. Airfield Fill

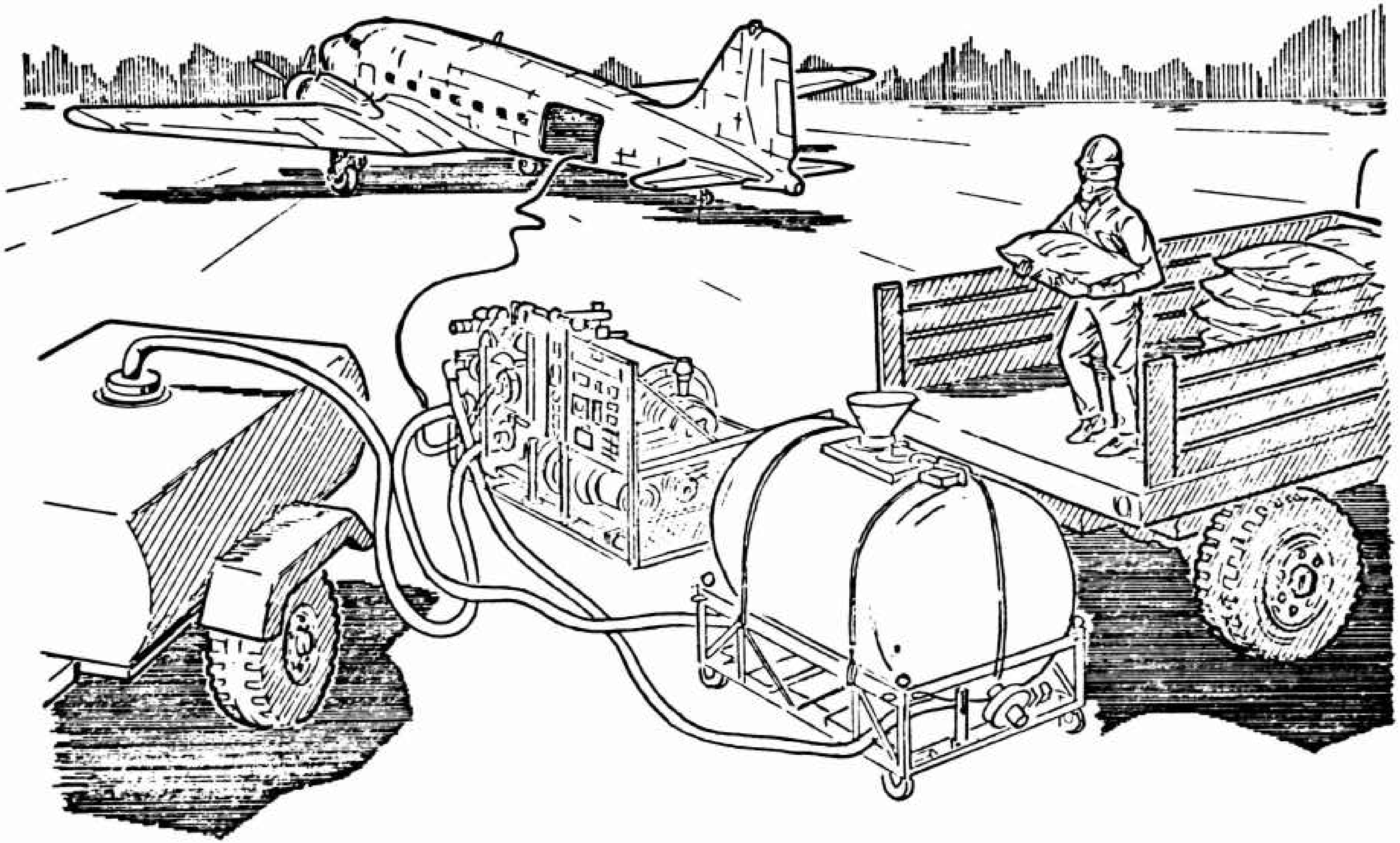


Figure 58. Mixing/Filling Operation with Wettable Powders

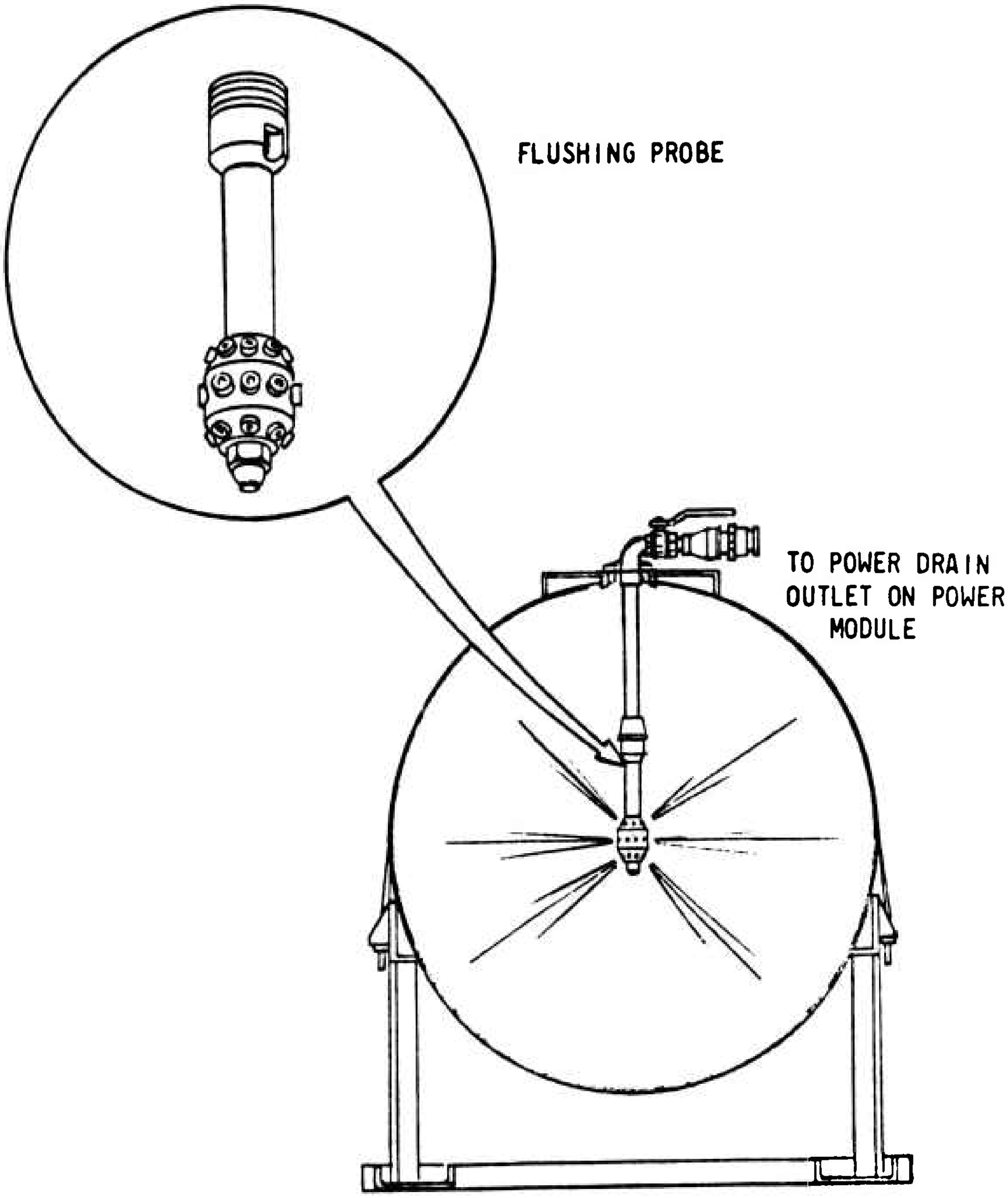


Figure 59. Tank Flushing

4.11 RELIABILITY AND MAINTAINABILITY

A basic functional level breakdown of the system is shown in Figure 60. These diagrams were generated by functionally dissecting each block. The process stops when the next dissection would result in specific part identification.

Analytical reliability and maintainability studies were not completed due to a change in the scope of the contract. Several key hardware components were cycle tested through a 5-year life, as explained in paragraph 4.14, Category I Testing.

Reliability requirements were that the system have a probability of mission success of 0.99 at a confidence level of 90 percent when disseminating an agent with viscosity of 350 cp at a flow rate of three gallons per acre.

Maintainability requirements were that the system be capable of operation away from a military installation for periods of up to six months with a spares kit containing only seals and nozzles. No field or higher maintenance was to be designed for a service life of 500 hours when disseminating agents Orange, Blue, and White. The nozzles (excluding tips, cores, and diaphragms) were to have a minimum predicted service life of 400 hours when disseminating agents Orange, Blue, and White. The nozzle tips and cores were to retain their calibration accuracy for a minimum time period of 10 hours. The flowmeter was to retain its calibration accuracy for a minimum period of 10 hours when disseminating agents Orange, Blue, and White.

4.12 SAFETY CONSIDERATIONS

Requirements specified that operational use of the dispenser system, including ground loading, must not be hazardous to personnel. As a result, the complete agent transfer system (including tankage) was designed as a sealed system with all agent vapors vented overboard both during ground and flight operations. In addition, both the lead-acid power module battery and the gas tank vents were routed overboard. All power train mechanisms (belts, pulley, etc.) were adequately shielded from operating personnel. A centrifugal pump was used as the prime agent mover and, due to system design, the pump could be operated at stall conditions without danger to the equipment or operating personnel. The power and tank modules were provided with captive castors to simplify system installation and removal and minimize danger to personnel. Pressure relief valves were provided on both the primary and emergency dump pneumatic systems, and all electrical systems were protected by individual circuit breakers. Adequate system instruments and controls provided the operator with complete system monitoring capabilities. All indicator lights were the press-to-test type.

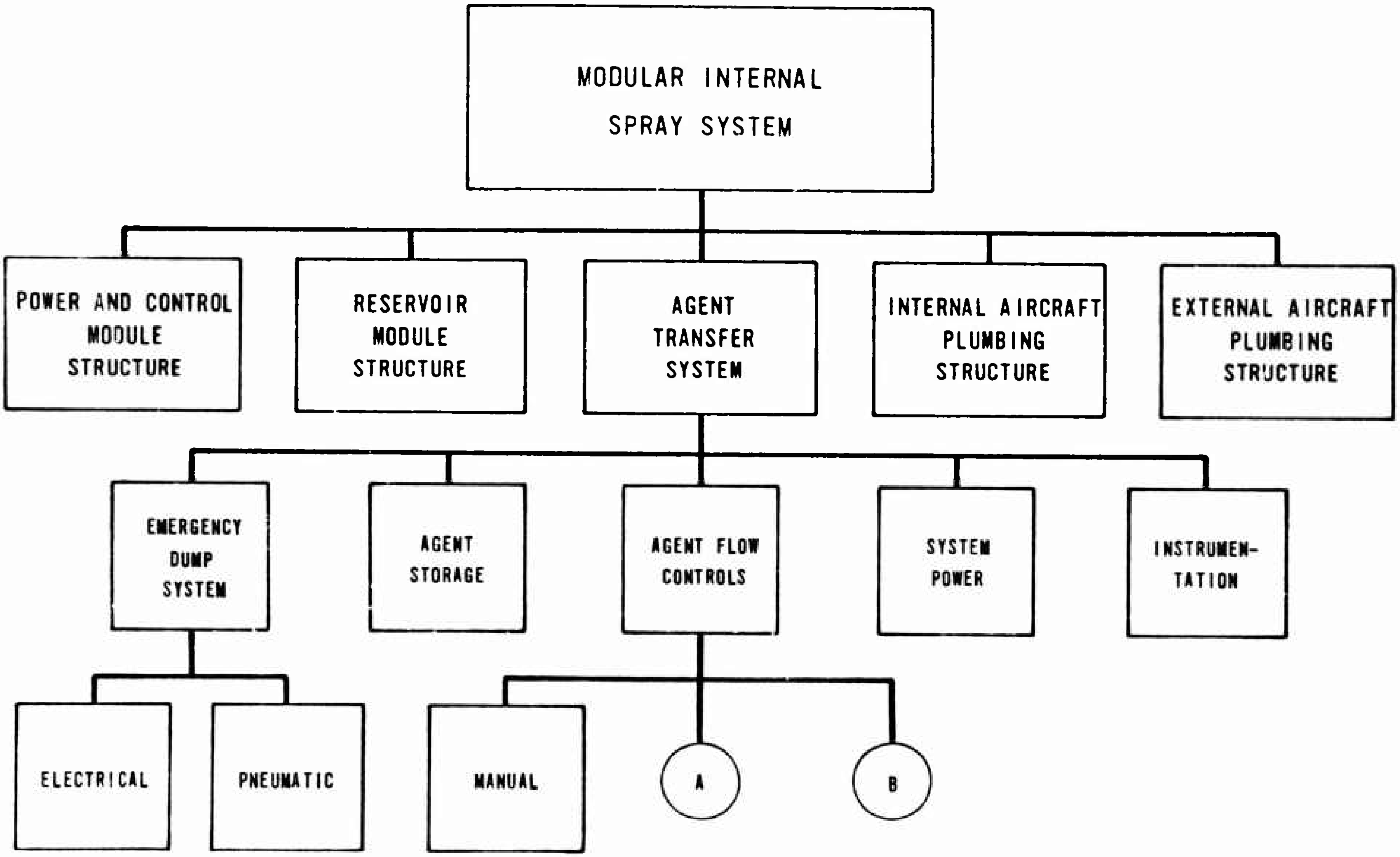


Figure 60. Functional Level Diagram for the Modular Internal Spray System

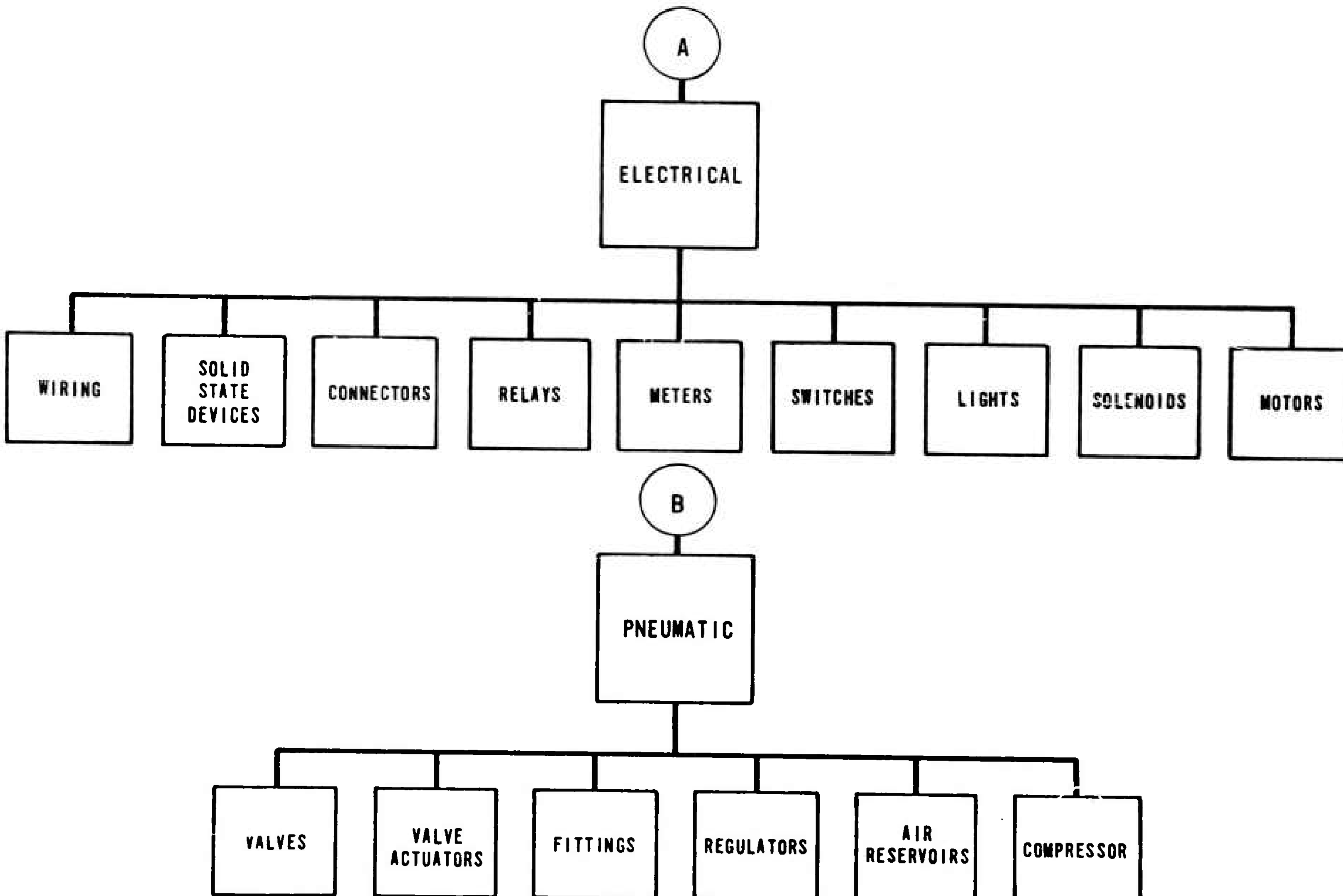


Figure 60. Functional Level Diagram for the Modular Internal Spray System (Concluded)

The entire system is structurally sound, conforming to all applicable aircraft technical orders. The internal hardware is tied down to withstand normal flight and crash g loads. The external hardware is designed to withstand the maximum flight speed of each applicable aircraft.

4.13 VALUE ENGINEERING

Throughout the development phase, the MISS was constantly analyzed to reduce costs without compromising performance, reliability, or maintainability. Specific examples of cost savings are:

- Used standard off-the-shelf hardware extensively.
- Used Government-furnished engine to reduce logistic problems.
- Selected modified cross-linked polyethylene high pressure hose to replace costly TFE hose.
- Provided complete ground support capabilities built into the power module.
- Designed the agent transfer system to adequately control c.g. while minimizing the number of hardware components.
- Selected 500-gallon-capacity tank modules to replace previous 325-gallon tanks, thus reducing costs, installation time, and plumbing complexity.
- Replaced TFE dump and vent ducts with silicone-coated glass at a substantial cost savings.
- Changed flange seals to reduce seal costs by 90 percent without compromising performance.
- Designed the electrical system to use a single type of switch and relay to minimize logistics.
- Changed to corrosion weight flanges to reduce hardware costs and parasitic weight.

4.14 CATEGORY I TESTING

Category I Contractor Testing was performed by DTL in three phases: Component Testing, Reliability Testing, and Reliability Retesting. Appendix II contains summaries of these reports.

Component testing was performed to determine operating characteristics of prime system components such as the pneumatically operated valves, eductor, air compressor, and flowmeters. Also included in the tests were agent/material compatibility, ground

operations, 500-gallon tank sealing, and emergency dump. Reliability retesting consisted of several cycling tests with the nozzle valve to verify a 5-year diaphragm life.

All components tested performed as designed and exceeded the 5-year life requirement.

4.15 CATEGORY II TESTING

The MISS C-123K system installation and aircraft modification was performed at Eglin Air Force Base, Florida from 27 April 1971 to 7 May 1971. The installation progressed smoothly, and only a few pieces of minor hardware were modified for improved functionability.

System flight tests were started on 17 May 1971 and included:

- Dry system flight compatibility.
- High volume spray, dump and manual dump using water as an agent.
- Full takeoff and landing (880 gallons glycerin/water solution).
- High volume spray at 240 gpm using glycerin/water solution; included turns while spraying.
- Full load flight compatibility.
- Low volume spraying.

During all tests, the system performed well with no major complications. The self-supporting features of the system proved effective. The aircraft pilot said the system felt solid, did not adversely affect flight characteristics, and agent slosh was not perceptible even with the tanks half full (maximum slosh condition). The system operator stated the operation was simple, straightforward, and all controls were positioned for easy handling.

Slight spray contamination of the right aft fuselage from the right-hand fuselage spray station was eliminated by plugging that spray nozzle. The contamination was apparently due to the vacuum created by the dump chute or due to the direction of the propeller vortices, since the left-hand fuselage spray station caused no contamination. Emergency dump contamination of the fuselage was as expected, but some internal spray-back was apparent since the dump chute was mounted forward in the jump door. The dump chute was consequently positioned aft in the jump door for future MISS aircraft designs. The pilot felt that manual emergency dumping took too long for combat missions but would be fine for non-combat-type spraying.

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SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. Flight characteristics of the C-123 aircraft are not adversely affected by the installation of the PWU-5/A MISS kit.

2. Maximum payload capabilities of all ten applicable aircraft are effectively utilized.

3. The system self-supporting features perform effectively.

4. The system exceeds required flow rates for all ten aircraft.

5. The system can be readily installed at the organizational level using standard tools.

6. The system is safe.

7. The spray nozzle valves effectively prevent agent leakage during maximum airborne maneuvers.

8. The flowmeter system is functional and meets the contractual accuracy requirements.

9. The emergency dump system will dump at least one-half the agent payload in 45 seconds.

10. Operator and pilot controls provide effective system monitoring and adjustment and meet human engineering requirements.

11. The agent transfer system provides effective recirculation agitation.

12. The system extensively utilizes standard, readily available hardware.

13. The agent reservoir design adequately prevents agent slosh.

14. The sequential tank-emptying design allows maximum modular installation flexibility.

15. Attachment of external hardware and limited internal hardware by bonding is an effective modification method.

16. Polysulfide or polysulfide/epoxy adhesive should be investigated to replace the epoxy wing boom bonding agent; the PWU-5/A MISS installation would then require no permanent aircraft modification.

17. The self-restraining wing boom connectors should be replaced with non-self-restraining connectors of the same type and used with fluorosilicone seals. Connection restraint should be done with mechanical ties between wing boom sections.

18. A cable system should be designed to allow manual emergency dump operation from the operator's console.

APPENDIX I

ELECTRICAL SYSTEM DESCRIPTION

I.1 MAIN POWER SYSTEM

The electrical power system consists of a 24-volt lead-acid aircraft battery (AN3150-2A), a 30-volt carbon pile voltage regulator (FSN 6110-373-8691), a 10-ampere maximum reverse current relay (FSN 2925-554-6956), and a 50-ampere, 28.5-volt aircraft direct current generator (FSN 2920-873-4396). Figure I-1 shows a simplified diagram of the main power circuitry.

When the generator voltage reaches 26 to 27 volts, the generator is connected to the battery by the reverse current relay allowing charging current to flow. The charging voltage is regulated to 30 volts by the carbon pile voltage regulator.

When the engine speed is decreased, the generator voltage drops, causing a reverse current to flow, discharging the battery through the generator. The reverse current relay disconnects the generator from the battery when the reverse current exceeds 10 amperes (engine idle).

I.2 CIRCUIT BREAKERS

The main power is monitored by the ammeter before being distributed to the secondary circuit breakers by the primary circuit breaker, CB-1, which is a d.c. 50-ampere, medium delay circuit breaker. The medium delay allows all tank vent valve motors to start at once without causing nuisance trips. The secondary circuit breakers are shown in Table I-1, and their delay curves are shown in Figure I-2. All circuit breakers are double pole.

Each of the circuit breakers is equipped with an auxiliary microswitch which, when the circuit breaker is tripped, will light the breaker-tripped indicator light on the main control panel. The toggle action on these circuit breakers is trip-free, making it impossible to hold the circuit closed against a fault. All circuit breakers are weather-proofed.

I.3 FLOWMETER

The flowmeter is supplied with 24-28 Vdc by circuit breaker CB-2 through connector P-11, as shown in Figure I-3. Inputs from the 1-inch and 3-inch turbine meter magnetic pickups are received at the flowmeter instrumentation package through cables W-4 and W-5. These are two-conductor shielded cables with the shields insulated at the flowmeter connector and grounded at the instrumentation package connector.

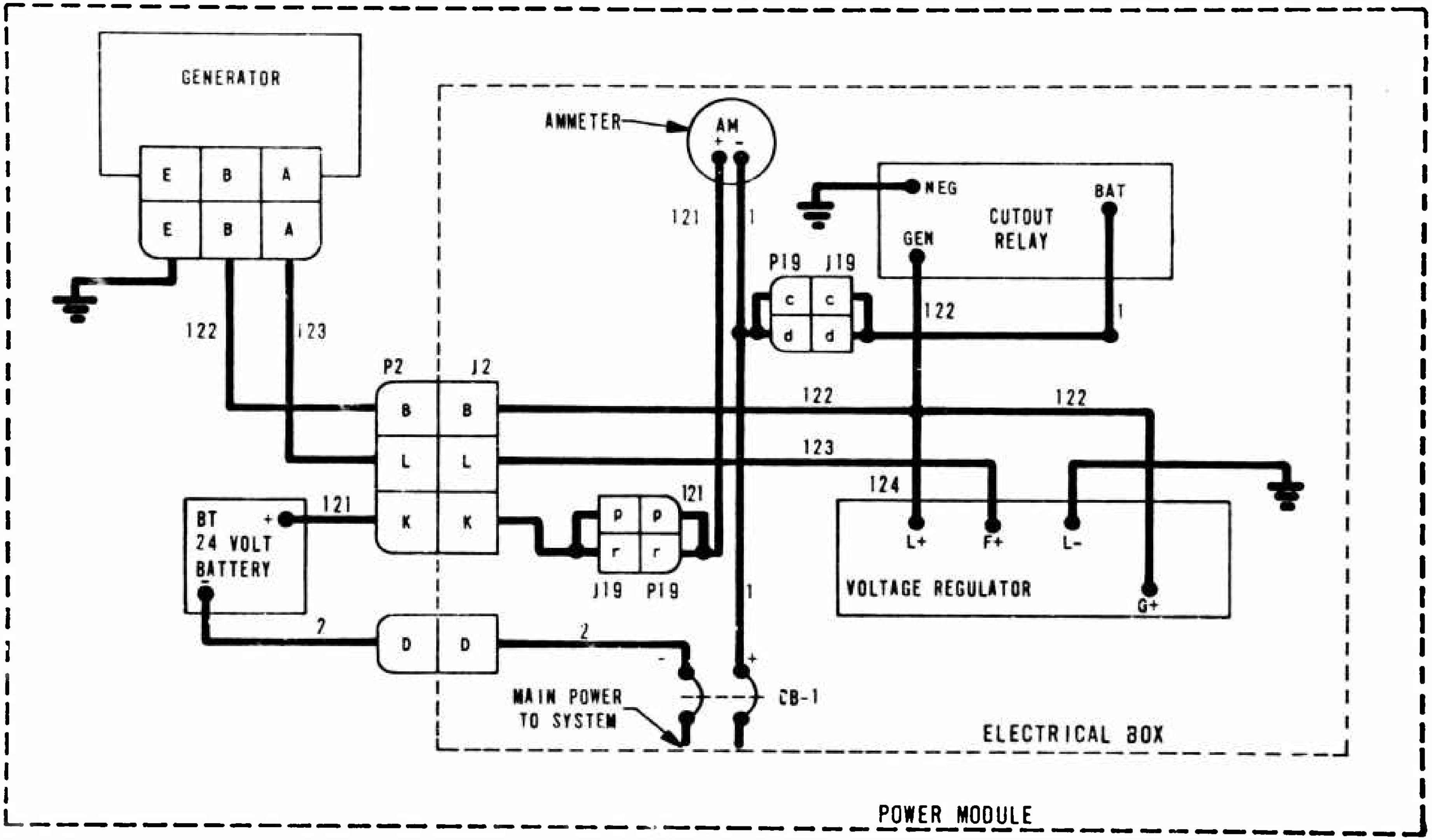


Figure I-1. Main Power Circuitry

TABLE I-1

SECONDARY CIRCUIT BREAKERS

BREAKER	LOAD (max)	RATING (amps)	DELAY
CB-2 FLOWMETER	.080	1.00	1
CB-3 ENGINE	3.450	7.50	1
CB-4 PANEL LIGHTS	.340	2.50	1
CB-5 PUMP PRIME	4.920	2.50	1
CB-6 DRAIN	4.500	10.00	2
CB-7 AIR PURGE	.820	2.50	1
CB-8 AGENT LEVEL	.400	1.00	1
CB-9 SPRAY	5.980	10.00	2
CB-10 DUMP	20.740	30.00	2
CB-11 VENT	19.360	30.00	2
CB-12 PILOT	19.360	30.00	2

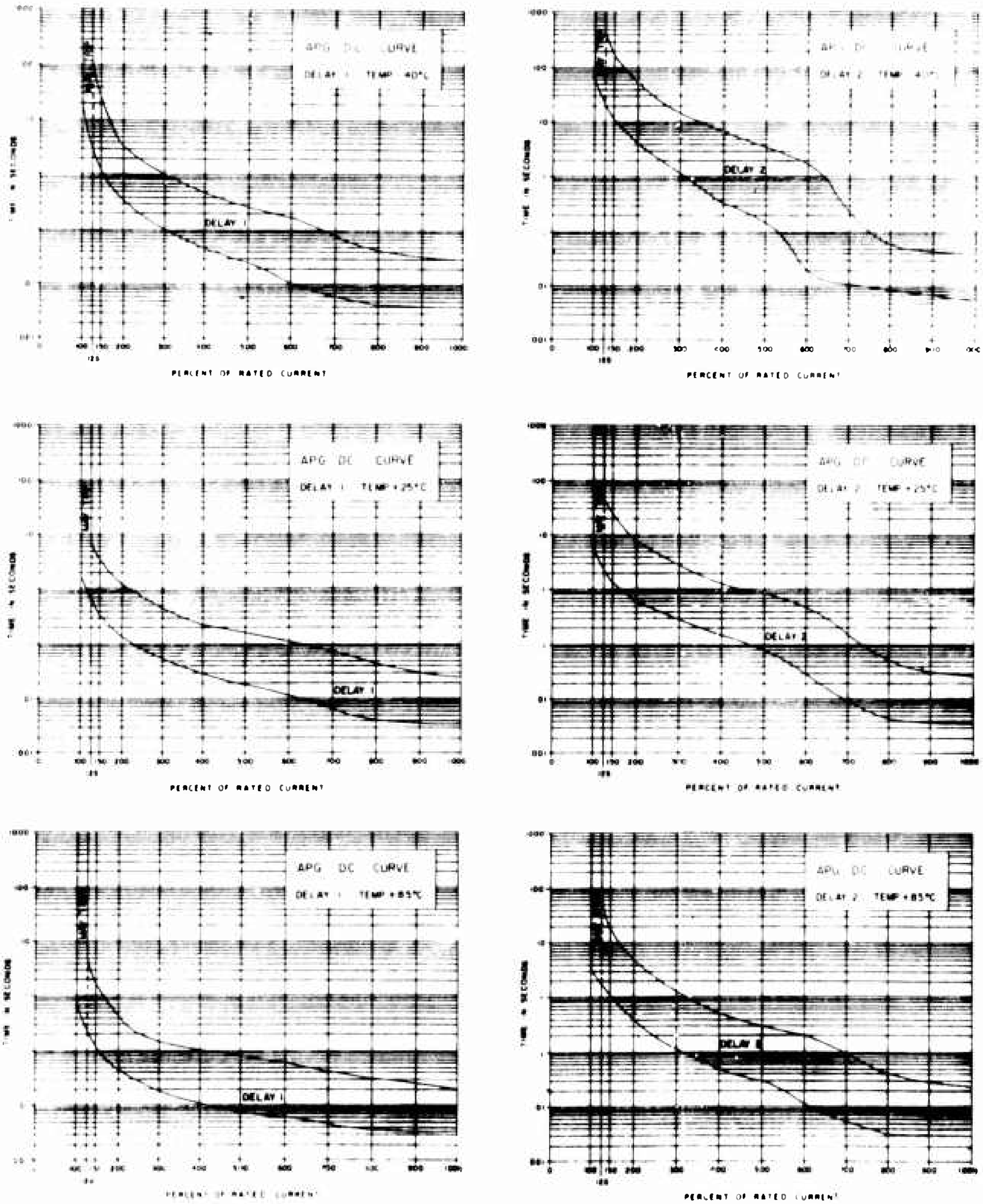


Figure I-2. Circuit Breaker Delay Curves

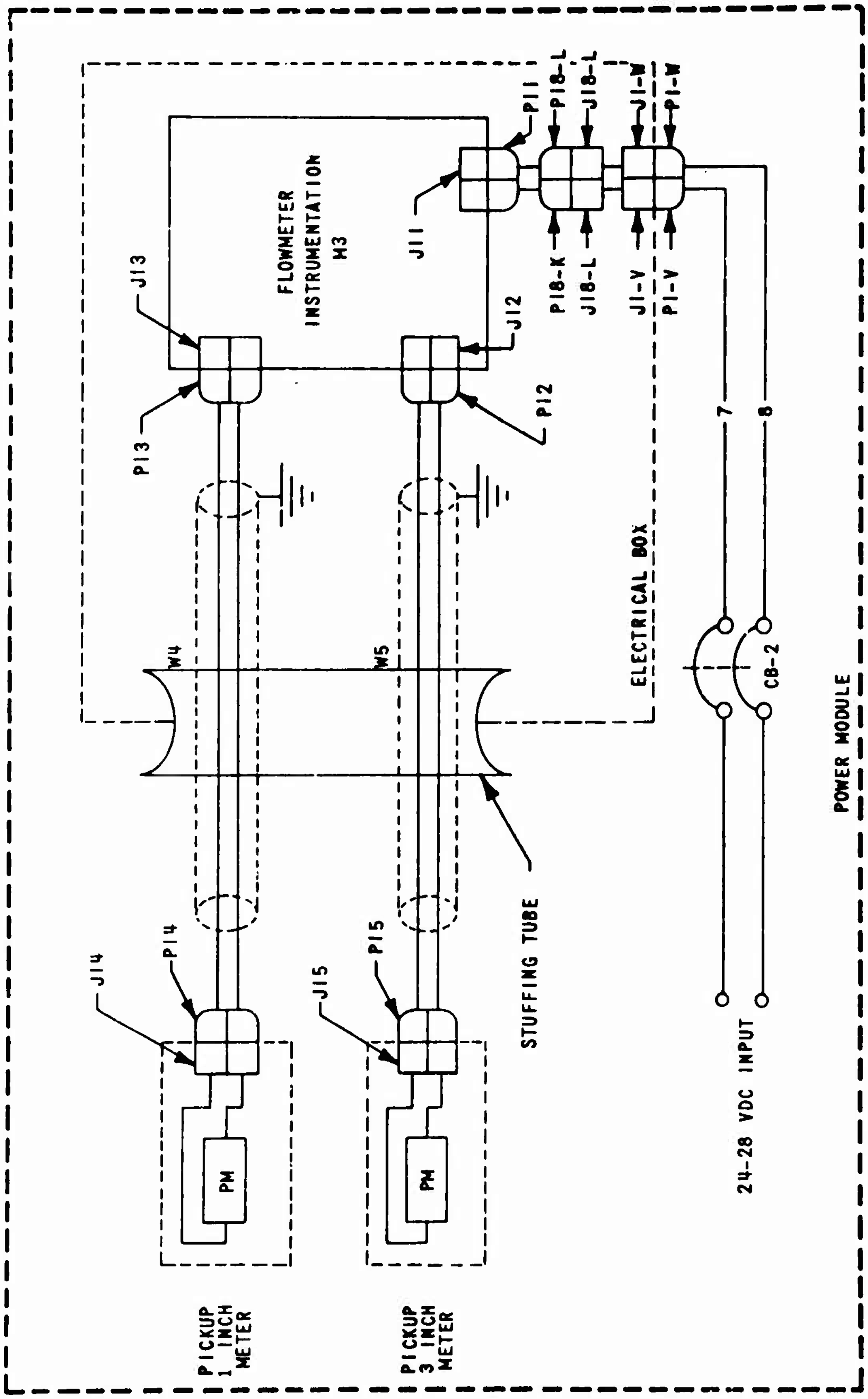


Figure I-3. Flowmeter Circuit

I.4 ENGINE

Power is supplied to the engine electrical controls through circuit breaker CB-3, as shown in Figure I-4. When the ignition switch (S-1) is switched on, power is supplied to the hourmeter and ground is supplied to the starter pushbutton (S-13). When S-1 is in the off position, the engine magneto is grounded and 24 Vdc is supplied to the normally opened contact of the oil pressure-actuated microswitch (S-16). If S-1 is switched off with the engine running (S-16 actuated to the normally opened position by oil pressure), 24 Vdc is supplied to the fuel shut-off solenoid until oil pressure decreased, allowing S-17 to deactuate to the normally closed position. This function prevents possible engine backfiring if the ignition switch (S-1) is switched off with the engine operating at high throttle settings. If the oil pressure drops too low with the engine running (S-1), S-16 deactuates and the fuel shutoff solenoid is energized with power from the magneto.

I.5 PANEL LIGHTS

Power is supplied to the two gooseneck panel lights through CB-4. Each of these lights has its own intensity-controlling rheostat.

I.6 PUMP PRIME

Power is supplied to the pump prime switch through circuit breaker CB-5. The pump prime switch opens the vent valves on the end tanks, removes power from the closed side of the vent valves, and energizes the eductor air solenoid valve.

I.7 DRAIN

Power is supplied to the drain switch through circuit breaker CB-6. The drain switch opens the vent valves on the end tanks and removes power from the closed side of the vent valves.

I.8 AIR PURGE

Power is supplied to the air purge switch through circuit breaker CB-7. The air purge switch energizes the air purge solenoid and the wing boom nozzle valve air solenoid. The positive power coming from CB-7 is in series with the spray switch so that the air purge switch will not function unless the spray switch is in the off position.

I.9 AGENT LEVEL

Power is supplied to the agent level system through circuit breaker CB-8. The power is dropped through a 75-ohm, 25-watt resistor or a 50-ohm, 25-watt resistor, depending on the number of tanks in the system used. The total number of tanks in the

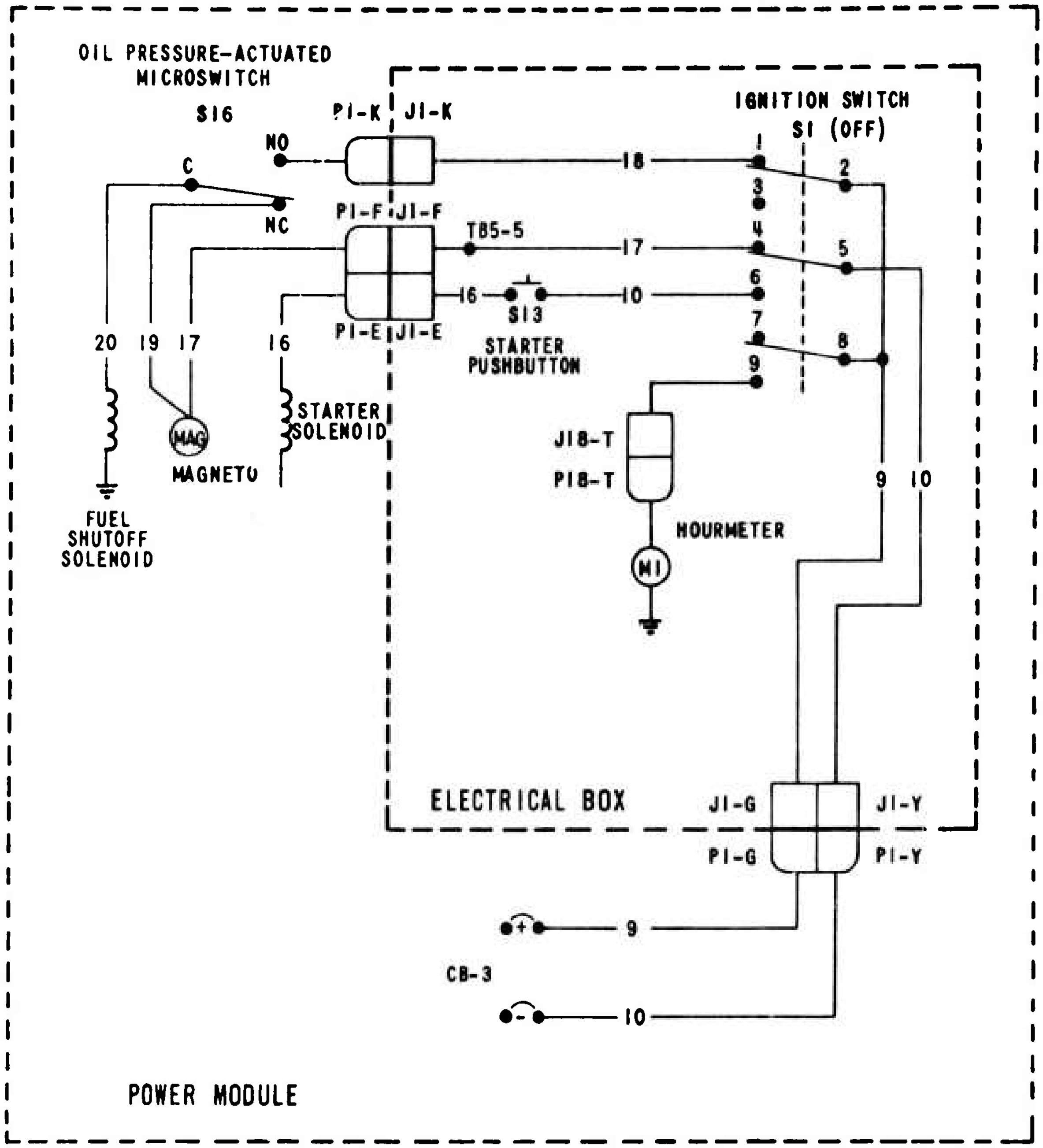


Figure I-4. Engine Control Circuit

system used is selected on the number of tanks switch (S-12) at the top of the control panel. This switch also programs the automatic engine cutoff circuitry for the number of tanks used. (Refer to Figures I-5 and I-6.)

The agent level system consists of a tank selector switch (S-5) and a dual meter readout (M-2). The tank selector switch receives the incoming signals from the tank sending units.

Tanks are selected in pairs to be read out on the dual meter. The sending units in the tanks consist of a sealed resistance comb running from the top to the bottom of the tank (70 ohms) with a sealed reed switch at the top. A floating magnetic runner causes the resistance of the circuit to change and actuates the reed switch at the top when the tank is full. The closing of this reed switch on each tank actuates some or all of relays K-9 through K-16, depending on the number of tanks used. The relays form part of a 2 to 8 input "and" gate, which shuts the engine down when all tanks are full. This automatic shut-down will only occur when the fill switch is in the "on" position.

I.10 SPRAY

The spray function, as shown in Figure I-7, is supplied with power through circuit breaker CB-9 and controlled by switch S-6 on the main control panel and switch S-14 on the pilot's control box. These two switches are wired in series so that the decision to spray must involve both the operator and the pilot.

Positive power from CB-9 is supplied to terminals 2 and 11 of the operator's spray switch, S-6. When S-6 is switched on, the operator's indicator light, L-9, on the main control panel is illuminated and positive power is supplied to the pilot's control box through CB-12, lighting the operator's indicator light on the pilot's control box, L-15. Terminal 5 of S-6 is part of the six input "and" circuits which supplys a closed signal to the vent valves. When S-6 is switched on, this closed signal is interrupted. Terminal 8 of S-6 is in series with the air purge function so that air purge cannot be operated during the spray function.

When S-14, the pilot's spray switch, is switched on, the end vent valves are opened through power from terminal 2. Terminal 5 of S-14 has received power from S-6 through CB-12. When S-14 is switched on, the spray solenoid and the wing boom nozzle air solenoid are energized with power from terminal 5. Terminal 3 of S-14 has power provided by CB-9. When S-14 is switched on, the pilot's spray light, L-11, on the pilot's control box is illuminated with power from terminal 3. The pilot's spray light on the main control panel, L-10, is also illuminated.

To summarize this function, when the operator actuates his spray switch, the operator's spray lights on the main control panel and on the pilot's box are both illuminated. When the pilot actuates

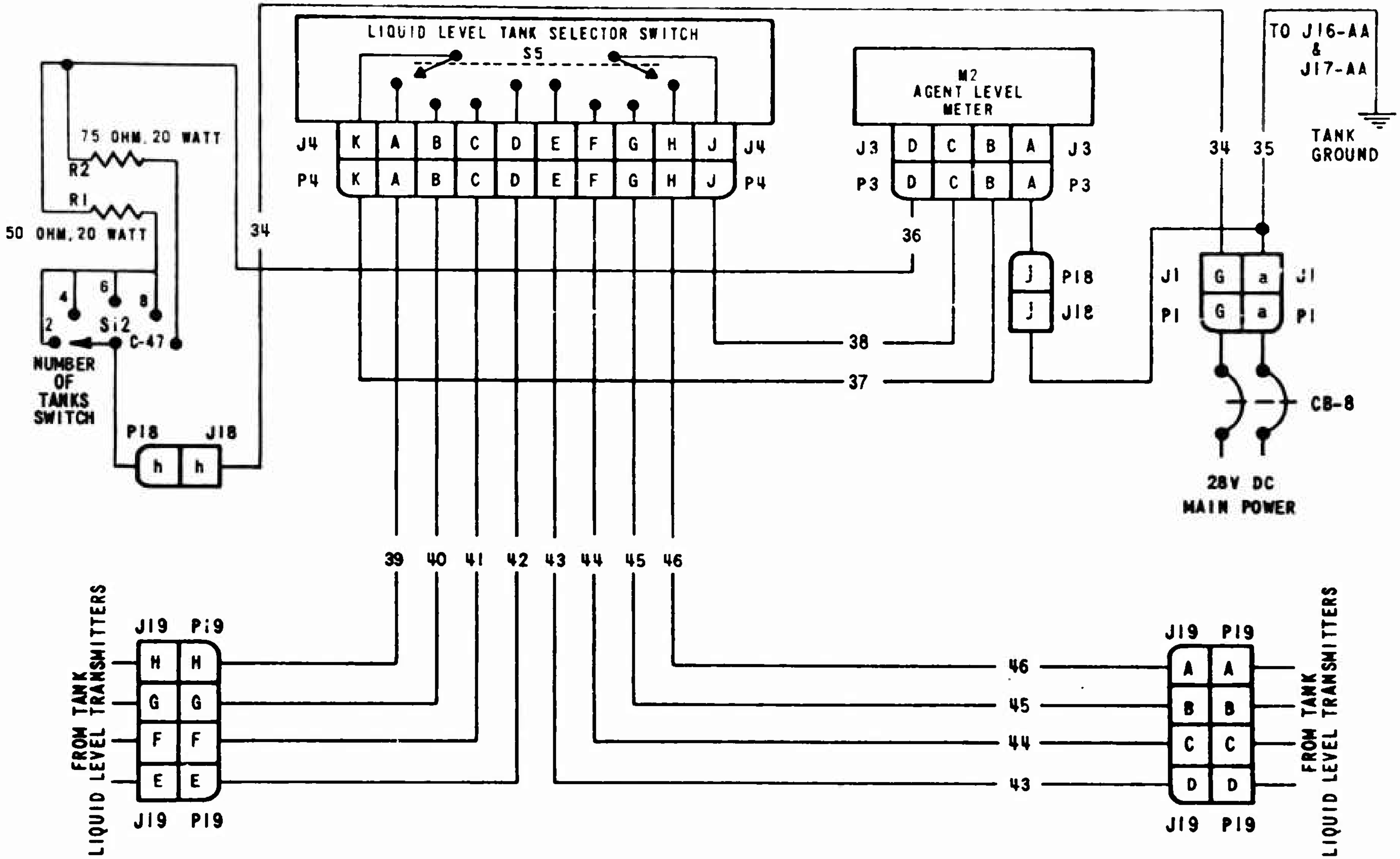


Figure I-5. Agent Level System Circuit

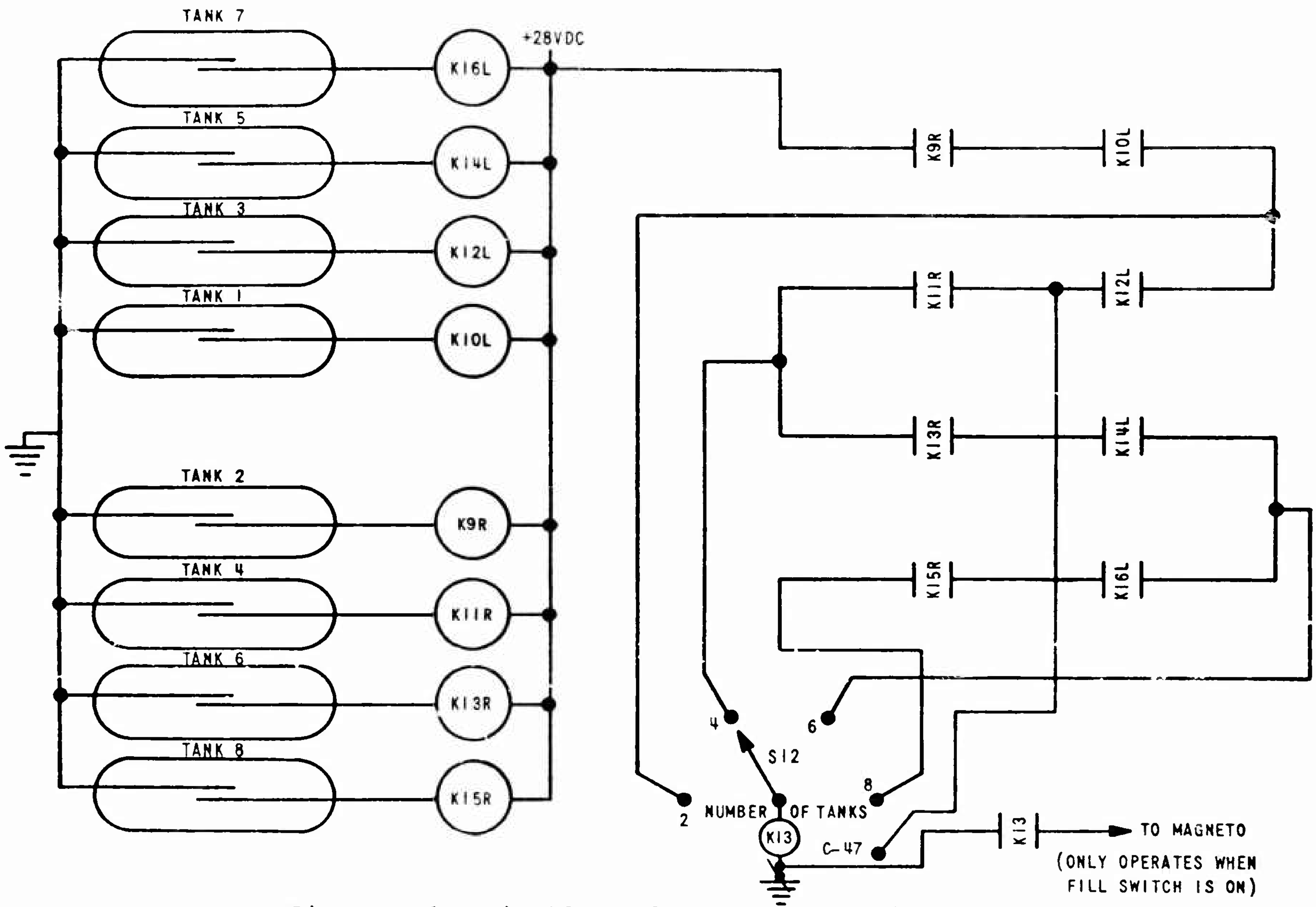


Figure I-6. Liquid Level System Automatic Engine Shut-off Electrical Schematic

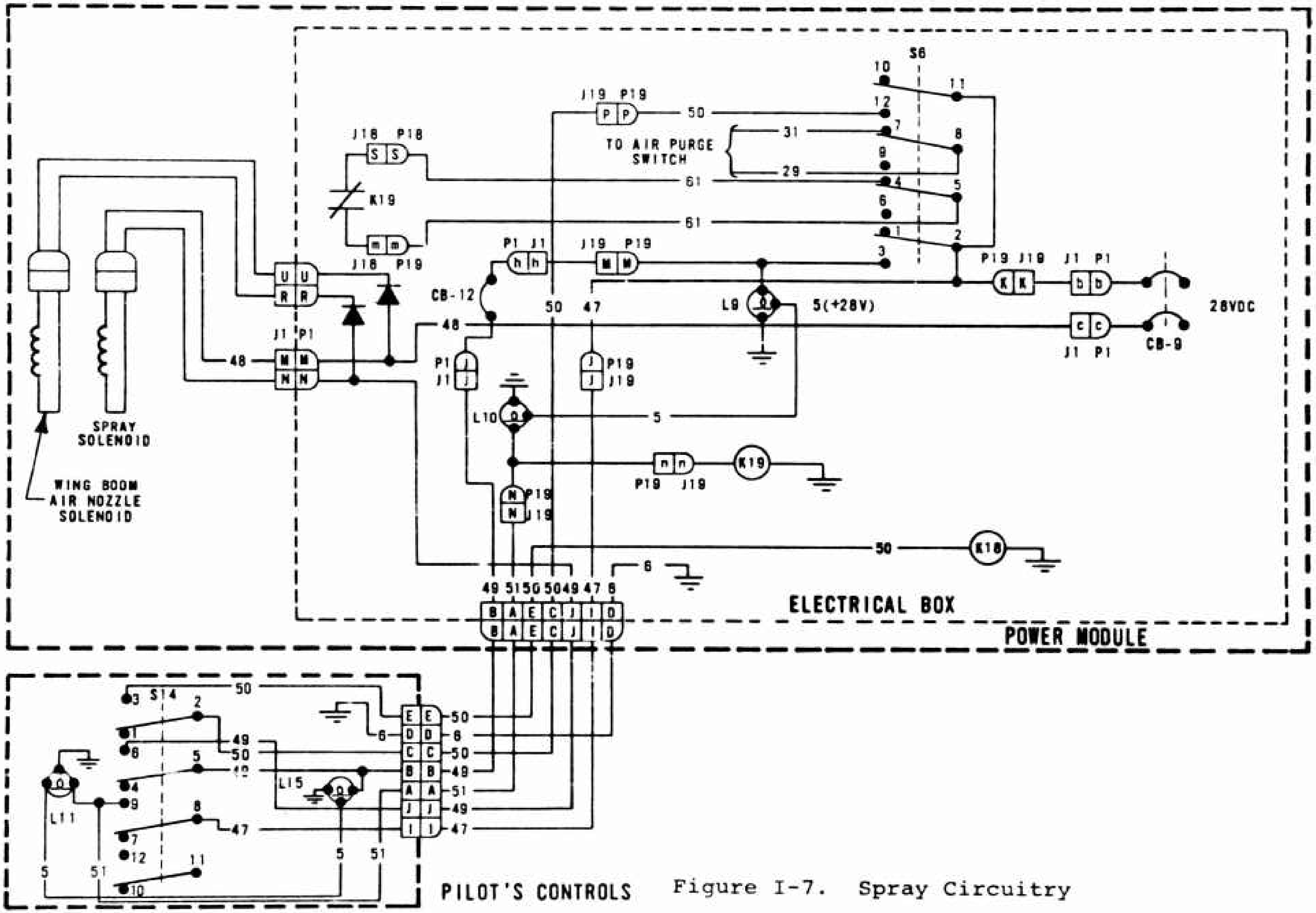


Figure I-7. Spray Circuitry

his spray switch, the pilot's box and the main control panel indicators are illuminated, the end tank vent valves are opened, the wing boom nozzle air solenoid is energized, and the spray solenoid is energized. The same order of events occurs if the pilot's spray switch is actuated before the operator's spray switch. However, the first switch to be turned off is the one which de-energizes the two solenoids and closes the vent valves.

I.11 DUMP

The dump function, as shown in Figure I-8, is supplied with power through circuit breaker CB-10 and controlled by switch S-7 on the main control panel and switch S-15 on the pilot's control box. These two switches are wired in parallel so that either the operator or the pilot can initiate the dump function.

Positive power from CB-10 is supplied to terminals 2 and 8 of switch S-7, the operator's dump switch. Negative power from CB-10 is supplied directly to the dump solenoid through P-1 and P-21. When S-7 is switched on, the operator's dump light, L-13, is illuminated, K-18 is energized through P-19 and D-19 cutting off the closed vent valve signal, the pilot's dump light, L-12, is illuminated, and all vent valves are opened through S-9. The pilot's dump switch will perform these same functions.

I.12 VENT VALVES

A logic diagram of this system is shown in Figure I-9, and a schematic is shown in Figure I-10. These figures show only one vent valve circuit since all are similar. Power is supplied to the vent valve system through circuit breaker CB-11. When the fill switch, S-8, is switched on, the vent valve is opened through the normally closed contacts of relay K-1. The open indicator light on the main control panel for that vent valve will light as will the closed indicator light when the valve is closed. When this tank is full, the agent level full switch is closed energizing relay K-1. The normally closed contacts on K-1 open, cutting off the open signal to the vent valve. The normally open contacts close providing a closed signal to the vent valve through S-8. Besides K-1 being energized, relay K-10L is also energized, which forms part of the engine shut-down circuit when all of the tanks are full. (See Figure I-6.)

Only when the fill switch is in the off position is power supplied to the S-9 open/closed switch. This switch either opens or closes the vent valves independent of the fill system.

The closed signal to the vent valves flows through a normally closed pole on:

- K-18, dump relay.
- S-7, dump switch.
- S-6, spray switch.

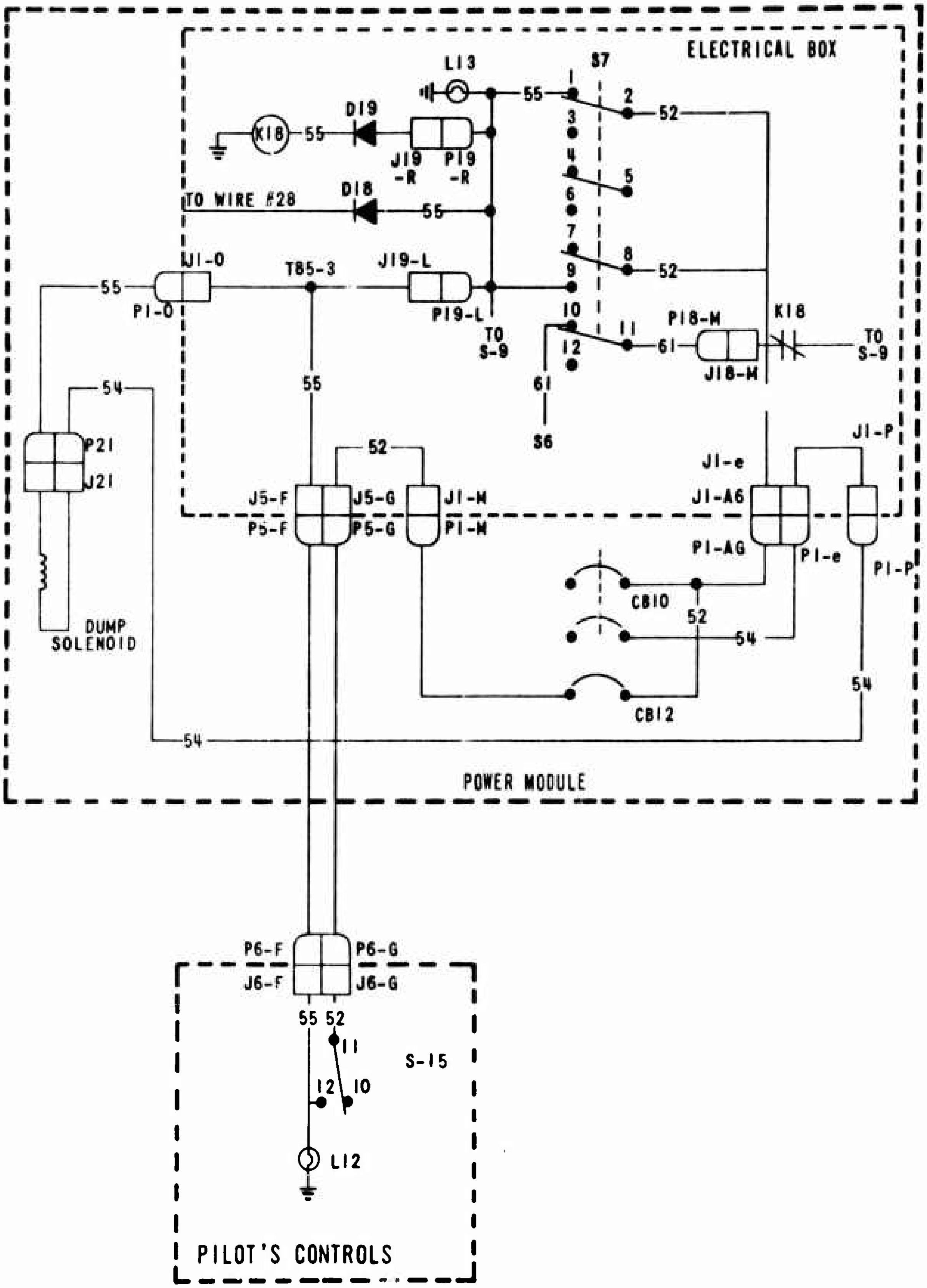


Figure I-8. Dump System Circuitry

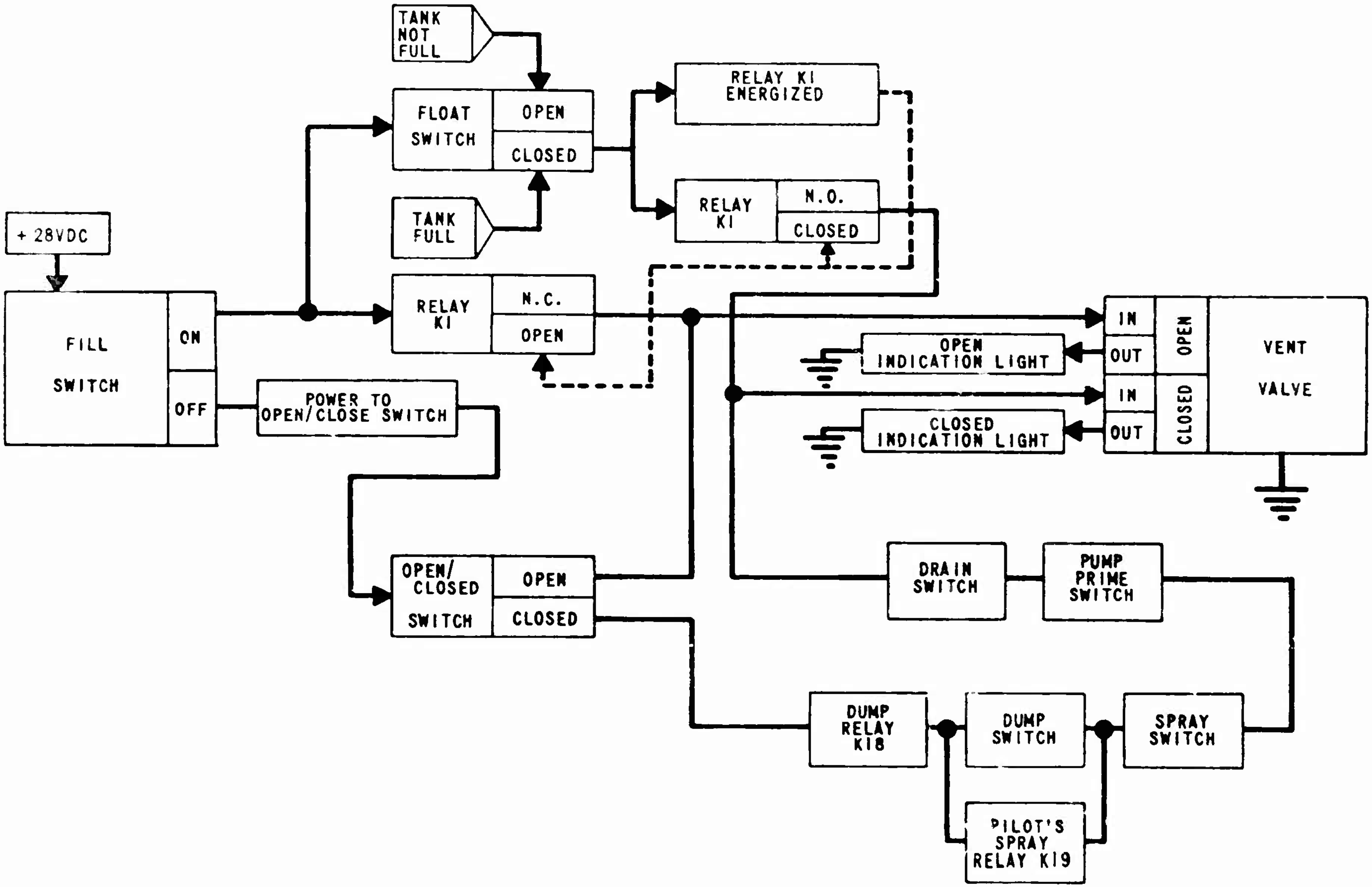


Figure I-9. Vent Valve Control System Logic Diagram (One Valve)

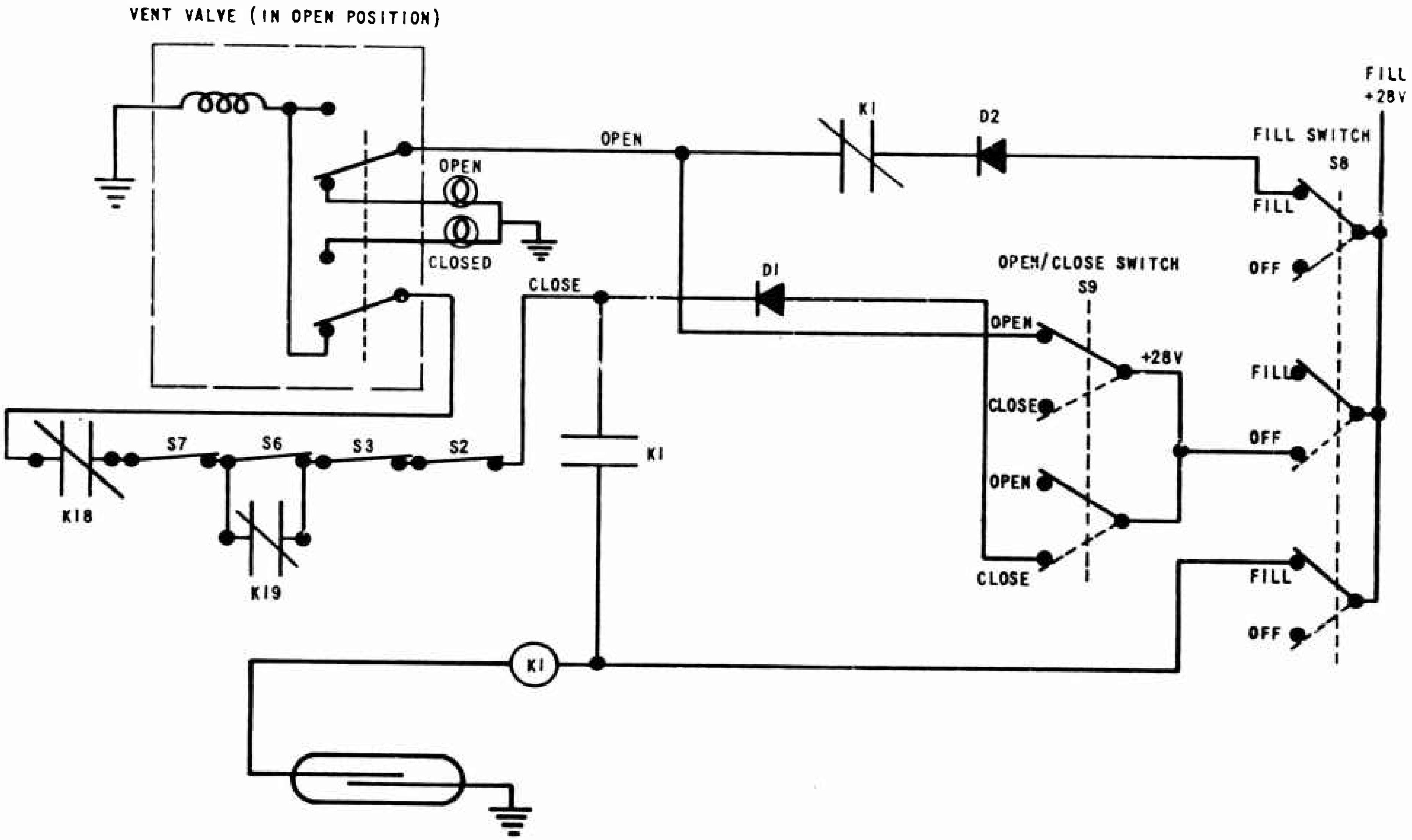


Figure I-10. Vent Valve Control System Schematic (One Valve)

- K-19, pilot spray switch.
- S-3, drain switch.
- S-2, pump prime switch.

The diodes (D-1 and D-2 in Figure I-10) in the vent valve circuitry are to prevent unwanted interaction between different tank systems.

APPENDIX II

CATEGORY I

TESTING REPORTS

Category I MISS testing consisted of the following:

- Component Tests
- Reliability Tests
- Reliability Retests

Summaries of the results of these tests are given in the following sections.

II.1 CATEGORY I COMPONENT TEST RESULTS

II.1.1 Introduction

From 25 May 1970 to 31 August 1970, DTL conducted the following MISS component tests:

1. Nozzle Valve
2. Motor-Driven Vent Valve
3. Dump Valve with Actuator
4. Spray Valve with Actuator
5. Sealing of 500-Gallon Tank Assembly
6. Agent/Material Compatibility
7. Centrifugal Pump Eductor
8. Suction Filling (55-Gallon Drums)
9. Air Compressor
10. Flowmeters
11. Emergency Dump System (500-Gallon Tank)
12. Emergency Dump (4 each 500-Gallon Tanks)

II.1.2 Results Summary

All components met or exceeded design parameters, except emergency dump. The 1-inch-diameter vent valve and vent tubes restricted tank venting too severely and dictated the use of 2-inch-diameter vent valves and vent lines. In addition, the dump chute and vent chute, which project into the air stream through the aircraft jump doors, were designed to allow ram air pressurization of the vent system and a slight vacuum condition in the dump duct system With these changes, emergency dump time requirements were met.

II.1.2.1 Nozzle Valve

The valve sealed drip tight against 58-psig water pressure with 40-psig air behind the diaphragm. With 0 psig air pressure, the valve sealed against approximately 6.5 psig water pressure. The valve absolutely eliminates water hammer effects since it readily opens at water pressures above the nominal sealing pressure.

II.1.2.2 Vent Valve

At 24 Vdc, the average opening and closing times were 1.9 seconds.

II.1.2.3 Dump Valve

With 100-psig air pressure, the average opening and closing times were less than 0.4 second.

II.1.2.4 Spray Valve

Opening time can be varied from 0.14 to 1.06 seconds, and closing time can be varied from 0.45 to 1.25 seconds.

II.1.2.5 Sealing of 500-Gallon Tank Assembly

All tanks were tested to 20-psig hydrostatic pressure. The tanks remained leak tight and structurally integral.

II.1.2.6 Agent/Material Compatibility

Agents used were: Dibrom (4.6 lb/gal - 3 oz/acre solution)
Orange
White
Blue

- Modified Cross-linked Polyethylene Hose

The modified cross-linked polyethylene hose withstood all agents at 140°F for 3-1/2 months with no degradation.

- TFE Lined 4-inch Suction Duct

The TFE liner withstood all agents at 140°F for two months without degradation. Constant exposure of the duct exterior to agents may cause slight delamination of the fiberglass layers.

- Silicone Vent and Dump Ducts

The silicone vent and dump ducts withstood all agents at 140°F for one month without degradation and withstood Orange, White and Blue for two months without degradation. The Xylene content of the Dibrom decomposed the silicone after two months of constant exposure at 140°F. This is equivalent to about eight months of constant liquid (agent) contact. Xylene will permeate the silicone duct in six days at ambient temperature. After drying, Xylene will repermeate the silicone after two days.

II.1.2.7 Eductor-Centrifugal Pump

- 50-Foot-Long, 2-Inch-Diameter Suction Hose

Height of Suction Lift	Time to Prime (sec)	Maximum Fill Rate (gpm)	Engine RPM
57 inches	15.4	145	1000
108 inches	17.9	130	1000
16.5 feet	26.0	125	1000

- 50-Foot-Long, 3-Inch-Diameter Suction Hose

System modification will have to be made to allow connection of 3-inch hose for ground fill - test performed for information only.

Height of Suction Lift	Time to Prime (sec)	Maximum Fill Rate (gpm)	Engine RPM
57 inches	24.4	390	1300
108 inches	28.5	390	1300
16.5 feet	41.0	250	1300

II.1.2.8 Suction Filling (55-Gallon Drum)

These tests were performed using the 50-foot-long, 2-inch-diameter suction hose with the drum probe assembly attached. Approximately one gallon of water was left in each 55-gallon drum when the probe began sucking air.

Height of Suction Lift	Time to Prime (sec)	Maximum Fill Rate (gpm)	Engine RPM
57 inches	20.0	75	1000
108 inches	22.5	70	1000
16.5 feet	27.0	50	1000

II.1.2.9 Air Compressor

Engine RPM	Time to Fill All Three Air Reservoirs to 128 psig from 0 psig (sec)
1000	283
1500	197
2000	144
2500	120
2750 (max)	112

II.1.2.10 Flowmeters

Size Flowmeter (inch)	Flow Range (gpm)	Indicated Flow (gpm)	Actual Flow (gpm)	Percent Error
3	0-600	100	100.977	0.97
3	0-600	300	288.11	3.96
3	0-200	100	100.469	0.47
3	0-200	50	51.311	2.62
1	0-60	41	40.644	0.86
1	0-60	15	15.048	0.32
1	0-20	15	15.128	0.85
1	0-20	1.5	1.5948	6.32*

II.1.2.11 Emergency Dump, Single 500-Gallon Tank

Using 1-inch-diameter vent valve and 84 inches of 1-inch-diameter vent line, time to dump one-half a full tank was 61 seconds. Water was used.

*Reading error was excessive percentage of error shown.

With the fill cap off, the time to dump one-half a full tank of water was 40 seconds.

Using a 2-inch-diameter ball vent valve with 5 feet of 2-inch vent hose, time to dump one-half a full tank of water was 41.7 seconds.

Addition of a blower which simulated ram air pressurization of the vent duct (about 6 inches of water pressure) decreased dump time by about 3 seconds.

II.1.2.12 Emergency Dump, Four 500-Gallon Tanks

Four 500-gallon tanks were manifolded into a single 10-inch-diameter duct. Using the 1-inch-diameter vent valves, one-half the agent (water) was dumped in 61 seconds.

With the fill caps removed, the tank nearest the dump discharge expelled one-half of its agent (water) in 42 seconds, and the fourth tank (furthest from discharge) expelled one-half of its agent within 48 seconds. The average time was 45 seconds. This test did not include ram air pressurization of the vent system nor the slight vacuum condition in the dump duct, both of which will decrease dump time and will occur during any aircraft flight.

II.1.3 Conclusions

All component testing has been successfully completed. With the previously described modifications to the emergency dump system, all system components are expected to equal or exceed the system design requirements.

II.2 CATEGORY I RELIABILITY TESTING RESULTS

II.2.1 Introduction

From 13 May 1970 to 9 June 1970, DTL conducted reliability tests of the following components:

- Vent valve with actuator
- Nozzle valve
- Spray valve with actuator
- Dump valve with actuator

The context and results of these tests are explained on the Test Information Sheets that follow. Included, also, is an explanation of Standard Component Certification.

II.2.2 Vent Valve Test Information Sheet

TEST CATEGORY:	Reliability
COMPONENT OR SYSTEM:	Vent Valve (McCannaflo 600, 1-inch F602-S3-T ball valve with Ramcon 8B-4 (WP) motor actuator).
DATE AND TIME TEST INITIATED:	13 May 1970, 0900 hours
DATE AND TIME TEST COMPLETED:	22 May 1970, 1145 hours

TEST OBJECTIVE:

The ball vent valve controls venting of the agent reservoirs and operates during filling, pump prime, and spraying. Normal air pressure on the valve is less than 4 feet of water.

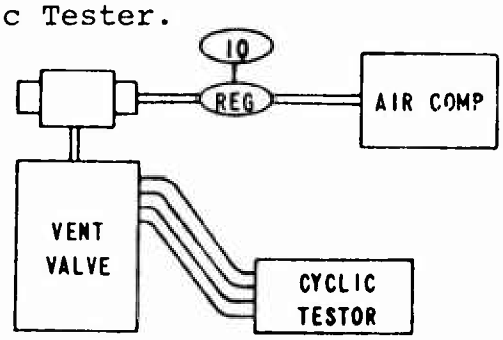
Test objective is to determine valve cycles to failure or prove active life is in excess of five years.

5-year life: 15 cycles/mission, 2/missions/day, 5 days/week, 52 weeks/year.

Total: 39,000 maximum cycles/5 years.

TEST DESCRIPTION:

The vent valve with actuator was installed as shown below. Differential air pressure across the valve was 10 psig The valve was opened and closed every 10 seconds by applying 24 Vdc to the Ramcon Actuator using the DTL Electrical Cyclic Tester.



TEST RESULTS:

The ball valve and motor actuator underwent 39,125 open/close cycles without failure. The ball valve was bubble tight against 10 psig air pressure.

TEST CONCLUSIONS:

The vent valve assembly will exceed the 5-year life requirement.

II.2.3 Nozzle Vent Test Information Sheet

TEST CATEGORY: Reliability

COMPONENT OR SYSTEM: Nozzle Valve (Spraying Systems No. 12328-NY-3/4, modified)

DATE AND TIME TEST INITIATED: 27 May 1970, 0830 hours

DATE AND TIME TEST COMPLETED: 1 June 1970, 1130 hours

TEST OBJECTIVE:

The nozzle valve is a diaphragm check valve modified to allow pressurization behind the diaphragm, increasing its sealing pressure. Normal air pressure behind the diaphragm valve will be 40 psig.

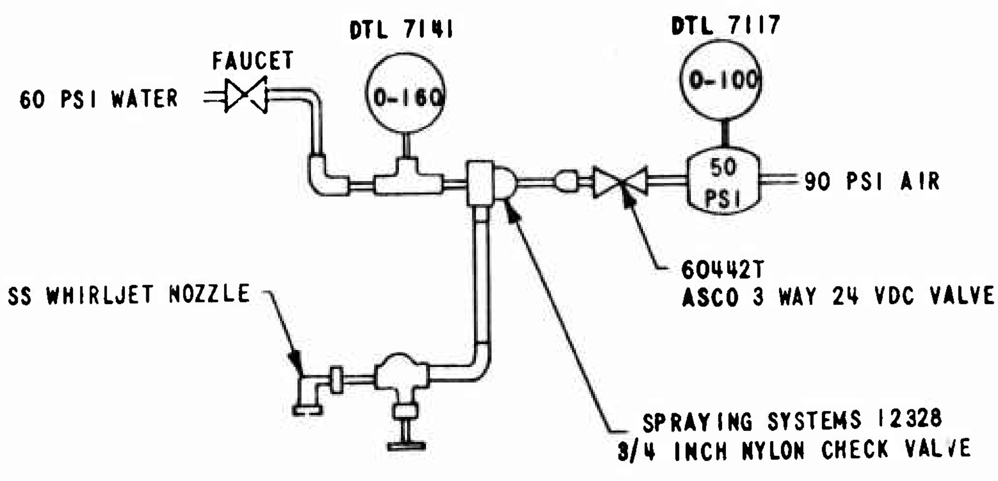
Determine cycles to failure or prove active life is in excess of 5 years.

5-year life: 10 cycles/mission, 2 mission/day, 5 days/week, 52 weeks/year.

Total: 26,000 maximum cycles/5 years

TEST DESCRIPTION:

The nozzle valve was installed as shown below. The water valves were adjusted so that water pressure on the diaphragm was 60 psig with the nozzle valve closed and 20 psig with the nozzle valve open. The nozzle valve was cycled open/closed by applying 24 Vdc to the ASCO 3-way valve using the DTL Electrical Cyclic Tester. Cycles were measured with a digital counter.



TEST RESULTS:

A standard nozzle valve was modified to allow air pressure behind the diaphragm and fitted with a 0.025-inch thick silicone-coated glass diaphragm. Air pressure was set at 50 psig. This diaphragm failed at 22,000 cycles due to a sharp edged stainless steel ring inside the valve.

The ring was removed (does not degrade valve); all sharp edges which the diaphragm would rub against were broken. In addition, a sealing ridge in the valve bonnet which had partially cut through the diaphragm was removed. A new 0.025-inch-thick silicone diaphragm was fit and testing resumed.

The diaphragm failed at 9485 cycles. Inspection of the diaphragm indicated that the glass fabric was powdering due to fatigue. Therefore, glass fabric was eliminated as a design choice.

A 0.050-inch-thick Buna-N coated Nylon fabric diaphragm was fitted and testing resumed. Buna-N is not compatible with the MISS agents; the purpose of the test was to fatigue test the diaphragm fabric. The diaphragm pulled away from the edges where it was compressed between the bonnet and valve body. This failure occurred after 200 cycles.

The bonnet was replaced with a standard bonnet complete with sealing ridge (machined off on previous bonnet). A 0.025-inch Buna-N coated nylon diaphragm was fitted and testing resumed using 40 psig air pressure. A total of 26,016 cycles was completed without failure. The diaphragm was removed and visually inspected for damage. Only slight wear was apparent.

The final diaphragm will be Fluorosilicone-coated Dacron.

TEST CONCLUSIONS:

Based on the test with Buna-N coated nylon, the final diaphragm should exceed the 5-year life requirements. Cyclic testing of the Fluorosilicone/Dacron diaphragms will be initiated as soon as they are received by DTL.

II.2.4 Spray Valve Test Information Sheet

TEST CATEGORY:	Reliability
COMPONENT OR SYSTEM:	Spray Valve (Weco Model 12, 3-inch butterfly valve with Worchester Model C38W pneumatic actuator)
DATE AND TIME TEST INITIATED:	22 May 1970, 1130 hours
DATE AND TIME TEST COMPLETED:	27 May 1970, 1420 hours

TEST OBJECTIVE:

The spray valve is a fully open or fully closed valve which controls agent release to the spray booms.

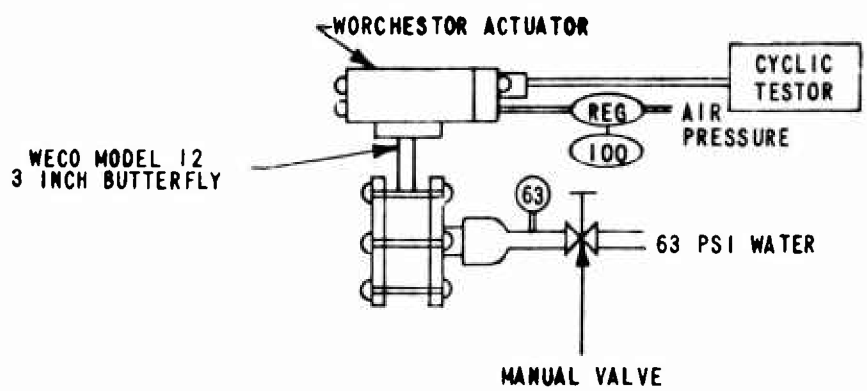
Test objective is to determine cycles to failure or prove active life is in excess of five years.

5-year life: 10 cycles/mission, 2 missions/day, 5 days/week, 52 weeks/year

Total: 26,000 maximum cycles/5 years

TEST DESCRIPTION:

The spray valve was mounted between 150-pound ASA flanges and mounted to the DTL water lines. Water pressure was 63 psig. The valve was opened and closed by supplying 24 Vdc to the solenoid of the Worchester Actuator using the DTL Electrical Cyclic Tester. Cycles were measured with a digital counter. Air pressure was 100 psig.



WATER MAIN PRESSURE = 63 PSIG

TEST RESULTS:

After 12,125 cycles, a slight leakage past the butterfly at the pivot points was noticed. The valve was left closed for two days, and the leakage stopped.

At 26,025 cycles, the same leakage was noticed. The ASA 150-pound flanges were retightened, and the leak was reduced to about two drops/minute.

The valve was left closed and mounted for two days. All leakage stopped. The valve was cycled ten times and remained leak-free.

Visual inspection showed slight TFE butterfly disc seat wear.

TEST CONCLUSIONS:

Rapid cycling of the valve (about 12,000 cycles/6 hours) tended to relax the TFE butterfly disc seat seal and allowed slight leakage. After setting for two days, the TFE seat returned to its original sealing position, eliminating all leakage. Cycling the valve an additional ten times did not reproduce the leak.

Based on the above, no leakage is expected during a normal 5-year life if the valve will be cycled about 20 times/day.

II.2.5 Dump Valve Test Information Sheet

TEST CATEGORY:	Reliability
COMPONENT OR SYSTEM:	Dump Valve (Weco Model 12, 4-inch butterfly valve with Model B38N Worchester actuator mounted)
DATE AND TIME TEST INITIATED:	2 June 1970, 1115 hours
DATE AND TIME TEST COMPLETED:	9 June 1970, 1055 hours

TEST OBJECTIVE:

The dump valve is a fully open or fully closed valve which controls release of agent from the tank to the emergency dump line. Agent pressure on butterfly is minimal (only the tank fluid head). Normal air operating pressure is 70 psig.

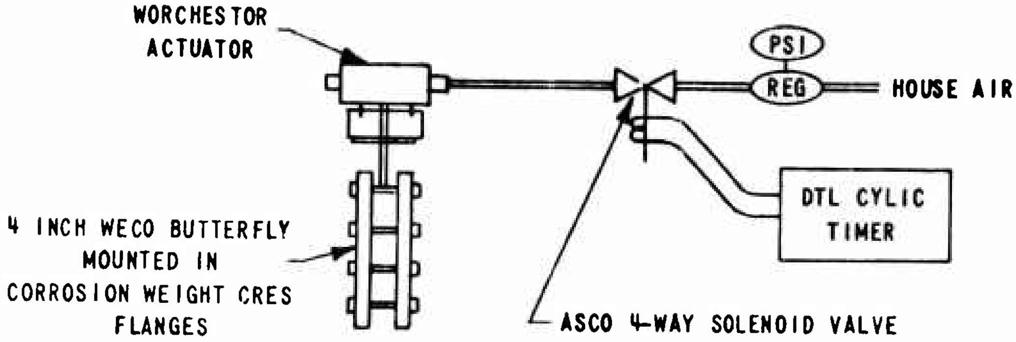
Test objective is to determine cycles to failure or prove active life is in excess of five years.

5-year life: 2 cycles/mission, 2 missions/day, 5 days/week, 52 weeks/year.

Total: 5200 cycles/5 years.

TEST DESCRIPTION:

The dump valve with actuator was installed as shown below. The butterfly valve was mounted between bolted flanges with the butterfly disc immersed in water and actuated, using regulated air pressure through a 4-way ASCO solenoid valve. The solenoid valve was actuated by applying 24 Vdc using the DTL Electrical Cyclic Tester.



TEST RESULTS:

Valve would not open at 70 psig but required 110 psig After five cycles, required pressure dropped to 65 psig. Operating pressure was increased to 100 PSI. After 2000 cycles the valve was closed and let stand for 2-1/2 hours, after which 70 psi air was required to actuate (open) the valve.

One-hundred psig cycling was continued. After 5500 cycles the valve remained leak tight. Visual inspection indicated no wear.

The valve was closed and let set for one day; opening pressure was 72 psig. The valve was closed and let set for six additional days; opening pressure was 78 psig.

TEST CONCLUSIONS:

The 5-year life requirement has been met and exceeded.

The original actuation pressure of 70 psig will have to be increased, as will the original air reservoir pressure of 100 psig. The air reservoir pressure can be increased to 125 psig maximum (maximum pressure available from the air compressor), and the valve actuator pressure can be increased to 110 psig.

Further testing of the dump valve actuation system will be performed during Category I Component Testing. Both the individual valves and the dump system will be tested.

Since minimal fluid pressure is seen by the valve, it may be possible to provide a spacer between the dump valve and its bolted flanges to allow less compression of the TFE seat, thus reducing the butterfly seating torque. This will not decrease the valve's sealing capabilities for the fluid pressures it will encounter.

II.3 CATEGORY I RELIABILITY RETEST RESULTS

II.3.1 Introduction

From 14 July 1970 to 23 July 1970, DTL conducted reliability retests of the nozzle valves with fluorosilicone diaphragm.

The context of these tests are explained in the Test Information Sheets that follow.

The final diaphragm configuration was cycled through 38,500 complete open/close cycles without any apparent wear on the components. A life duration of 7.38 years is equivalent to 38,400 cycles.

II.3.2 Nozzle Valve Test Information Sheet

TEST CATEGORY:	Reliability
COMPONENT OR SYSTEM:	Nozzle Valve (Spraying Systems No. 12328-NY-3/4, modified)
DATE AND TIME TEST INITIATED:	14 July 1970, 1515 hours
DATE AND TIME TEST COMPLETED:	23 July 1970, 1440 hours

TEST OBJECTIVE:

Previous testing of the nozzle valve during May 1970 indicated that a glass fabric diaphragm was not applicable since the fabric powdered due to fatigue. A nylon fabric diaphragm was tested and found to exceed the 5-year life requirement.

The nozzle valve was subsequently retested as explained below, using a dacron fabric diaphragm impregnated with Fluorosilicone (necessary for chemical agent compatibility).

A 5-year life is represented by a total of 26,000 on/off cycles as follows: 10 cycles/mission, 2 missions/day, 5 days/week, 52 weeks/year.

TEST DESCRIPTION:

The nozzle valve was installed exactly as was done for the previous testing (see June 1970 Category I Reliability Testing Results). Water pressure on the diaphragm was 60 psig with the valve open (no air pressure behind the diaphragm). Air pressure behind the diaphragm was regulated to 40 psig.

TEST RESULTS:

A standard Spraying System valve was modified to allow air pressurization behind the diaphragm, and the stainless steel annulus insert was removed as was done for previous tests. A Fluorosilicone diaphragm was fitted

and the valve was assembled hand tight. At 6,500 cycles the valve was disassembled for inspection. The diaphragm was severely cut where the bonnet sealing lip was holding the diaphragm in place.

The sealing lip was sanded down slightly to reduce the cutting effect, and a new diaphragm was fitted. The valve was reassembled. Testing was resumed and stopped after 27,621 cycles. The valve was disassembled and inspected. The diaphragm was cut at the bonnet sealing lip.

A new valve was modified for air pressure behind the diaphragm, the stainless annulus ring was removed, a new diaphragm was fitted, and testing was resumed. After 5,000 cycles, air was passing through the diaphragm. The diaphragm was again cut at the bonnet sealing lip.

The bonnet sealing lip was measured at 0.027-inch high, and the standard Spraying Systems diaphragm was measured at 0.027-inch thick. Therefore, it was felt that the bonnet sealing lip should be cut down to 0.015-inch high to try to eliminate diaphragm cutting.

A new bonnet was machined for a 0.015-inch high sealing lip. A new diaphragm was fitted and testing resumed. After 5,553 cycles, the test was stopped due to air leakage past the diaphragm. The diaphragm was cut.

At this point it was felt that cutting the Fluorosilicone could best be avoided by using the Fluorosilicone diaphragm in front of the standard Spraying Systems diaphragm and using a standard bonnet. This was tried and the test was stopped after 26,120 cycles.

No failure was noticed, but the Fluorosilicone diaphragm was cut in one place (due to sealing lip on bonnet). The Spraying Systems diaphragm was uncut.

Investigation of the slightly cut Fluorosilicone diaphragm indicated that overtightening of the bonnet clamping bolts was very likely the cause of the cutting.

New diaphragms were fitted, the bolts were torqued to 15 in.-lb , and testing was resumed. Testing was stopped after 30,720 cycles. Inspection of the diaphragms showed no cutting, but the Fluorosilicone diaphragm did have impressions of the Spraying Systems diaphragm cloth pattern.

Bolt torquing tests were performed and at 10 in.-lb the Fluorosilicone showed no effect; at 15 in.-lb , the Fluorosilicone retained impressions of the Spraying Systems diaphragm cloth pattern.

New diaphragms were fitted to the test valve, the bolts torqued to 10 in.-lb, and testing resumed. The test was stopped after 38,400 cycles. Inspection of the diaphragms showed no cutting or wear points.

CONCLUSIONS:

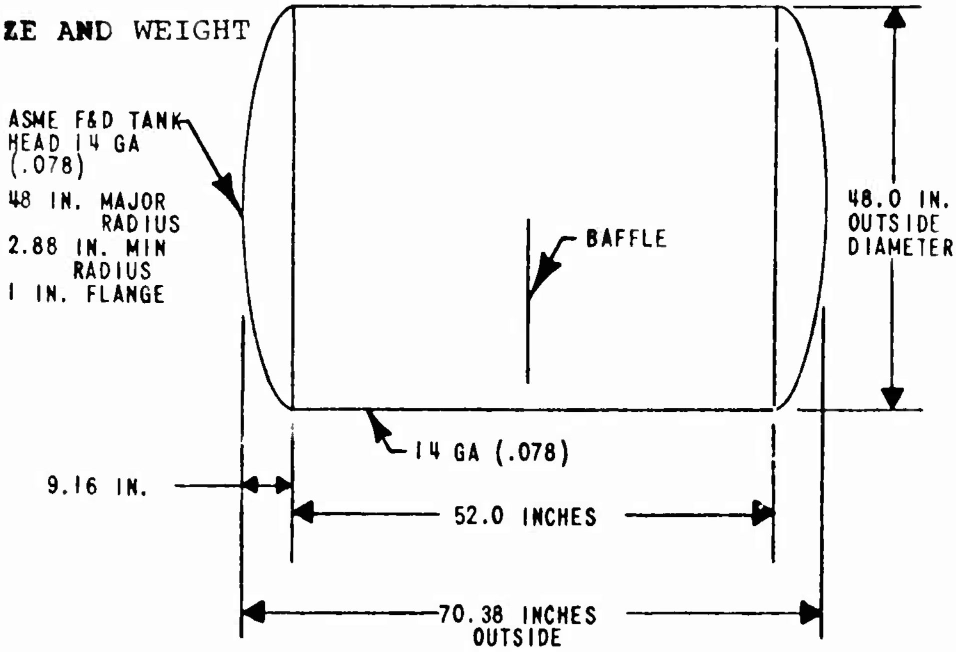
The Spraying Systems No. 12328-NY-3/4 diaphragm check valves can be successfully used as a MISS wing boom nozzle valve by performing the following modifications: use the Fluorosilicone diaphragm in front of the Spraying System diaphragm; use a standard bonnet modified only to accept air pressurization behind the diaphragm; torque the bolts to 10-12 in.-lb. The standard bolts should be replaced with the safety-wire-type bolts to prevent the possibility of accidental overtightening.

APPENDIX III

STRESS ANALYSIS

This appendix contains detailed calculations for the 500-gallon MISS tank and cradle. For analysis of the tie-downs and aircraft external plumbing, refer to each individual aircraft Class II modification documentation.

TANK SIZE AND WEIGHT



VOLUME:	Tank Head	-	48-inch, 12 gage standard volume including dish and inside corner radius = 38.22 gallons Ours is 48-inch, 16 gage ≈ 38.3 gal/head
	Cylinder	-	52.0 long by 47.844 diameter Add 2 inches for heads flange ∴ = 54 inches long by 47.844 diameter Volume $= \left(\frac{\pi}{4}\right)(47.844)^2(54)\left(4.329 \times 10^{-3}\ \frac{gal}{in^3}\right)$ $Vol_{cyl} = 420.05$
	Total Volume	-	2 heads @ 38.3 = 76.6 1 cylinder @ 420.05 496.65 Total Volume = 496.65 gallons

AGENT WEIGHT:

SG = 1.0, Tank Full, (496.65)(1)(8.34) = 4142

Agent Weight = 4142 pounds
SG = 1.0

WEIGHT

Tank Ends	Based on 48-inch, 12 gage (.109) with 2-inch flange =	74.9 pounds
	Less 1-inch flange (1)(Π)(48-.109) (.109)(.28) =	4.59
		70.31
	We have .078-inch thick, not .109	
	$.0\ \frac{.078}{.109}$ (70.31) = 50.31 pounds each	
Cylinder	52 inches long (Π)(48-.078)(52) (.078)(.28) = 170.9	
	2 each tank ends @ 50.31 =	100.62
	1 each cylinder	170.9
Total		271.52

Bare Tank Weight = 271.52

TANK & CRADLE ASSEMBLY WEIGHT

Tank

1 each Baffle	15.0
1 each Tank Complete	271.52
1 each Cap, Wisco	0.5
1 each Filler Neck, Wisco	0.5
1 each Valve, Ball, Ramcon Motor Driven	8.5
1 each Valve, 4-inch Butterfly, Weco w/Pneu Act	9.0
2 each Flange, 4-inch @ 8.25	16.5
1 each Tube, 4-inch OD x .065 wall	1.86
2 each Ferrule, 3-inch, Laddish @ .43	0.86
2 each Elbow, 3-inch Laddish @ 2.0	4.0
4 each Tri Clamp, Laddish, 3-inch @ 0.5	2.0
4 each Gasket, Laddish @ 0.5	0.1
2 each Elbow, 90°, 3-inch Tube @	3.06
2 each Elbow, 45°, 3-inch Tube @ 1.77	1.54
1.3 feet Tube, 3-inch	2.80
1 each Float, Level Indicator, Pneumercator	5.00 (est)
1 each Float Mounting Hardware	3.00 (est)
1 each Miscellaneous Weld Rod, Electric Wire, Hardware	20.00 (est)
TOTAL TANK ASSY	365.74 pounds

Cradle	New (final) cradle	
144 inches	Angle 4 x 2-1/2 x 1/4 @ 1.856 lb/ft	22.27
88 inches	Angle 4 x 3 x 1/4 @ 1.988 lb/ft	14.57
61 inches^3	Sheet .190 x 4 x 80" @ .098 lb/in^3	5.97
164 inches^3	Sheet .190 x 8 x 54" @ .098 lb/in^3 (2 each)	16.07
80 inches	Angle 3 x 3 x 3/16 @ 1.28 lb/ft	8.53
160 inches	Angle 1-1/2 x 1-1/2 x 1/8 @ .42 lb/ft (8 pieces 20" long)	5.59
200 inches	Angle 1-1/2 x 1-1/2 x 1/8 @ .42 lb/ft (8 pieces 25" long)	6.99
165 inches^3	Sheet 1/8 @ .098 lb/in^3	16.17
292 inches^3	Sheet 3/16 @ .098 lb/in^3	28.62
252 inches	Channel 5[2.32 @ 2.32 lb/ft	48.72
4 each	Castor, Darnell @ 3.18	12.70
4 each	Strap Assy, Marman @ 3.12	6.24
4 each	Pivot Block @ 2.9	11.60
4 each	Ball Lok Pins, Carr Lane @ .12	0.50
1 each	Lot Aluminum Weld Rod 5356	8.0
2 each	Padding, Strap @ 0.1	0.2
2 each	Jack, Marvel @ 5.0	10.0
4 each	Corner Block @ 4.0	16.0
4 each	Eye Bolts @ 4.0	16.0
1 each	Lot Paint	10.0
1 each	Electric Box, Elco	5.0
1 each	Electric Harness Assy	5.0
1 each	Lot Electric Wiring & Misc	5.0
	TOTAL CRADLE	279.78 pounds

TOTAL CRADLE ASSEMBLY = 279.78 pounds

DRY TOTAL TANK & CRADLE ASSEMBLIES = 645.52 pounds

WET TOTAL TANK & CRADLE ASSEMBLIES = 4788 pounds
Full SG = 1.0 agent

TANK HEAD STRENGTH

$$P = \frac{St}{0.885L + 0.1\ t}$$ (Pressed Metal Handbook) pg. 2A-10

where P = Design pressure (psi) (Maximum working pressure)
t = Wall thickness (inch) = 0.078
S = Maximum allowable stress (psi) [note 304σ yield = 40 Kpsi]
= 16,000 psi (200°F) page 2A-8, 304ss
L = Inside crown radius (inch) $\cong$ 48.0

$$P_{max} = \frac{(16,000)(.078)}{(.885)(48) + (0.1)(.078)}$$

$$\underline{P_{max} = 29.37\ psi}$$

Maximum Loading Pressure = (8g)(Fluid Head Pressure)

$$\text{Fluid Head Pressure} = \frac{(70")}{12"}\left(.433\ \frac{psi}{ft\ H_2O}\right) = 2.526\ psi$$

Maximum Loading Pressure = (8)(2.526)

<u>Maximum Loading Pressure = 20.21 psi</u>

Safety factor on working stress or working pressure

<u>SF = 1.45</u> on working stress (ASME) which has SF = 4 on material stress

TANK HEAD BUTT WELD STRENGTH

$$P = \frac{25\ t\ E}{R}$$

where S = Maximum allowable stress
t = Wall thickness
E = Joint efficiency
(single butt weld without backing strip)
R = Tank radius

$$P = \frac{(2)(16,000)(.078)(.6)}{24}$$

$$\underline{Pmax = 62.40 \text{ psi}}$$

Maximum Loading Pressure = 20.21 psi

S.F. = 3.09 on working pressure

TANK SHELL STRENGTH (INCLUDING LONG. WELD)

$$Pmax = \frac{S\ E\ T}{R + 0.6\ t}$$ (Pressed Metals Handbook, pg. 2A-18)

S = Maximum allowable working stress
E = 60% joint efficiency
t = Wall thickness 14 gage (.078)
R = Radius

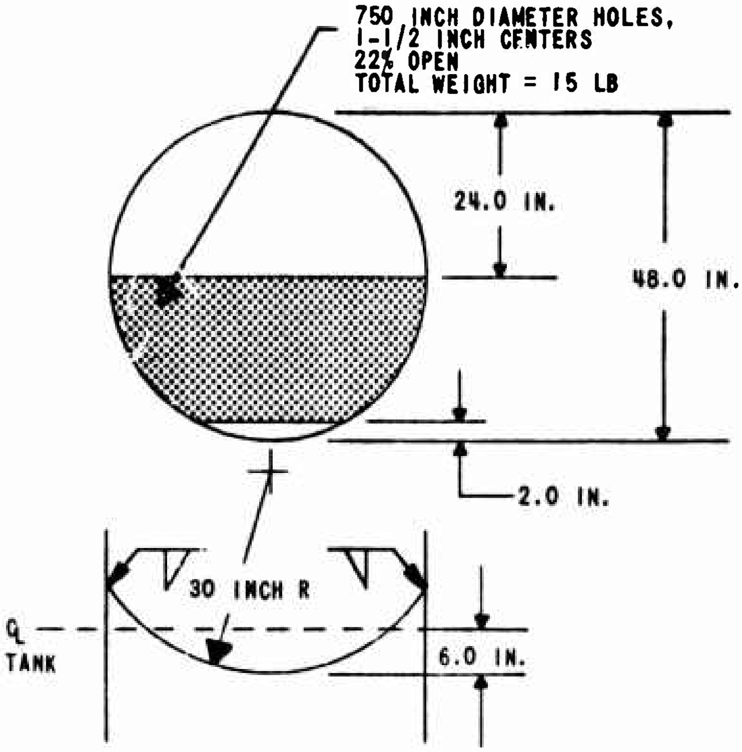
$$P_{max} = \frac{(16,000)(.078)}{24 + (.6)(.078)}$$

$$\underline{Pmax = 31.14 \text{ psi}}$$

Maximum Loading Pressure - 20.21 psi (8g forward - pressure @ forward tank end)

S.F. = 1.54 on working pressure

TANK SLOSH PLATE



Pressure: Assume tank 1/2 full sg = 2.0 agent at 8 g's. Assume full 35" head is seen by baffle plate.

$$P = \left(\frac{35"}{12}\right)\left(.433 \frac{psi}{ft\ H_2O}\right)(2)(8g)$$

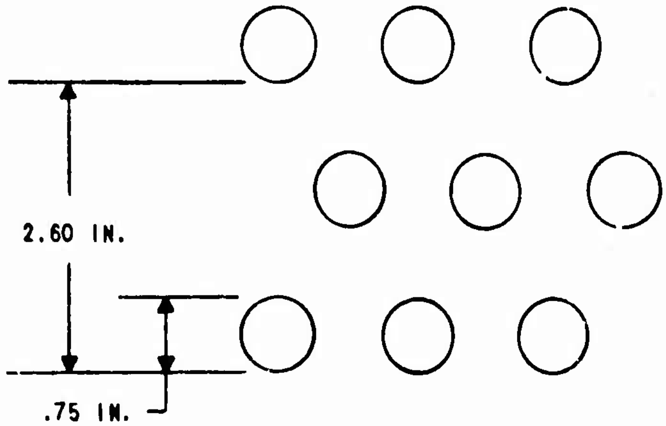
<u>Pmax = 20.21 psi</u>

Stress: For a 30" radius curved plate

$$\sigma = \frac{PR}{t} = \frac{(20.21)(30)}{.078} \qquad \text{(14 gage-.078 thick)}$$

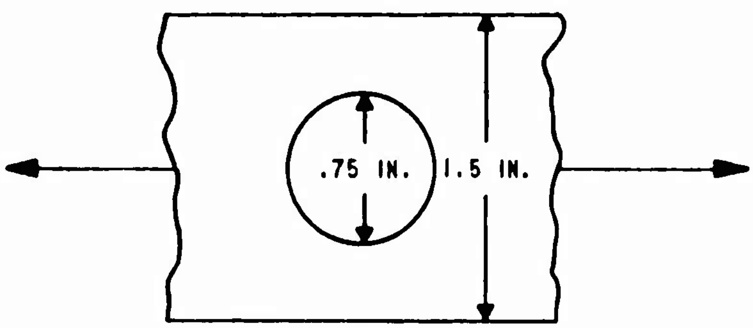
σ = 7773 psi

The perforated plate appears like



Cross sectional area is reduced by .750 inch in 2.60 inches which is 28.8% decrease in area or 71% the cross section area of a solid plate.

Stress concentration: Approximate like



Fron Shigley page 613,

$$K_t = 2.18$$

Therefore, $\sigma = \dfrac{(7773 \text{ psi})(2.18)}{71\%}$

$$\underline{\sigma = 23{,}866 \text{ psi}}$$

For 304ss, $\sigma_{yld} = 30$ kpsi minimum

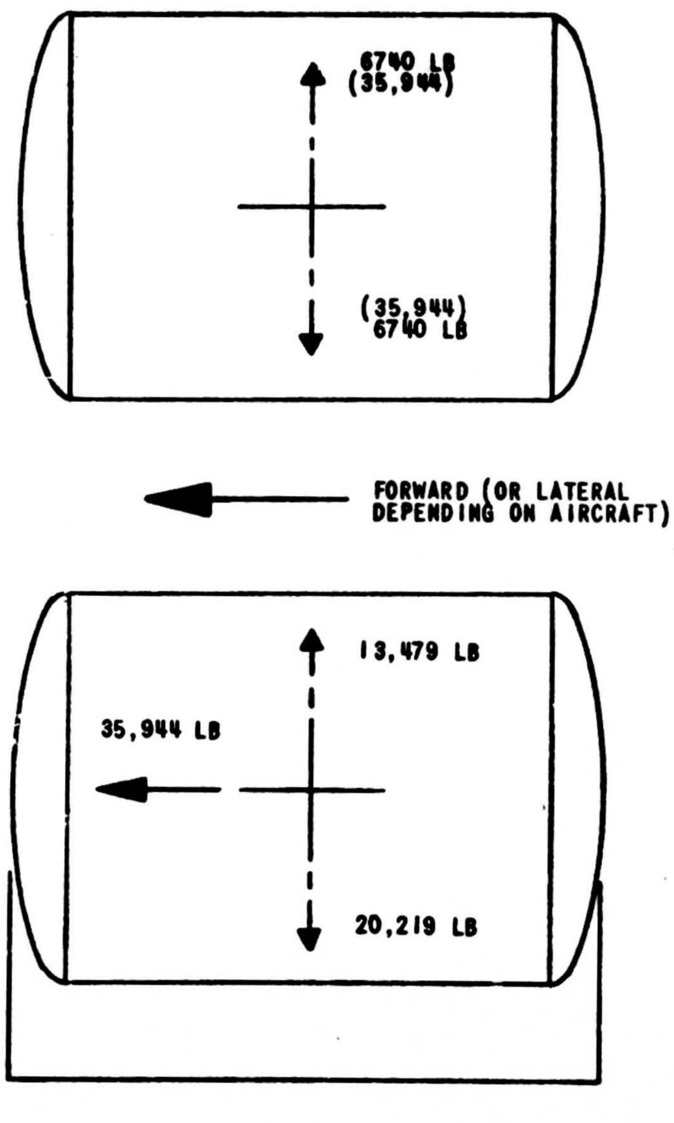
$SF = \dfrac{30}{23.886}$ $\underline{\underline{\text{S.F.} = 1.26}}$

Note: This is conservative since full 8g fluid head will never be seen by the baffle plate.

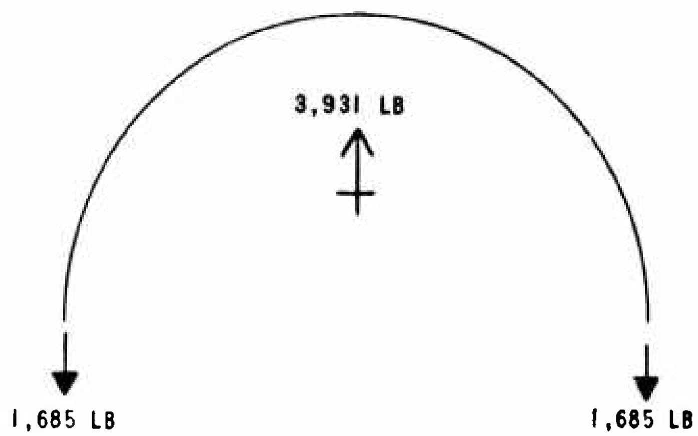
TANK/CRADLE INTERFACE

Tank (full sg = 1.0) = 4493 pounds (page 1 & 2)
Maximum Down Load Factor = 4.5g (normal and crash)
Maximum Forward Load Factor = 8.0g (crash) [3g normal]
Maximum Up Load Factor = 3.0g (normal)
Maximum Side Load Factor = 1.5g (normal & crash)

Then, loading of tank is as follows:



Vertical Load per Strap = 13,479/4 = 3370 pounds per strap



Strap is : MBB90857 .080 thick 301 Cres 1/4 Hard, 3/8 - 24 bolt (9350 yield) 431 Cres

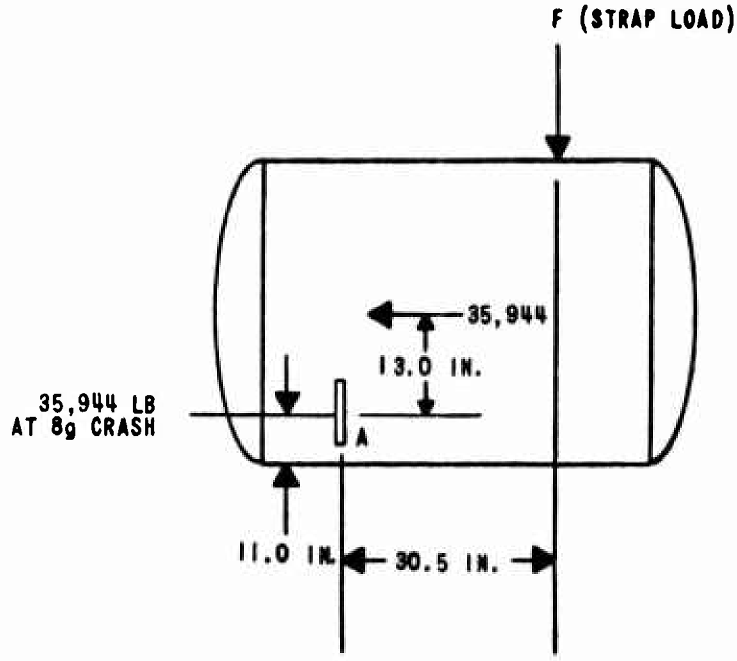
Minimum Band Yield Strength 12,000 pounds (page 45, Aeroquip 821-A)

$$SF = \frac{12,000}{1685}$$

$$\underline{\underline{S.F. = 7.12 \text{ yield}}}$$

HORIZONTAL FORWARD LOADING

Tank is prevented from slipping by interference at the lower tank supports



$\Sigma M_A = 0 \qquad (F)(30.5) = (35{,}944)(13.0)$

$\underline{F = 15{,}320}$

Strap Strength $= \frac{F}{2} = 7660$ pounds

$SF = \frac{12000}{7660}$

$\underline{\underline{S.F. = 1.57}}$

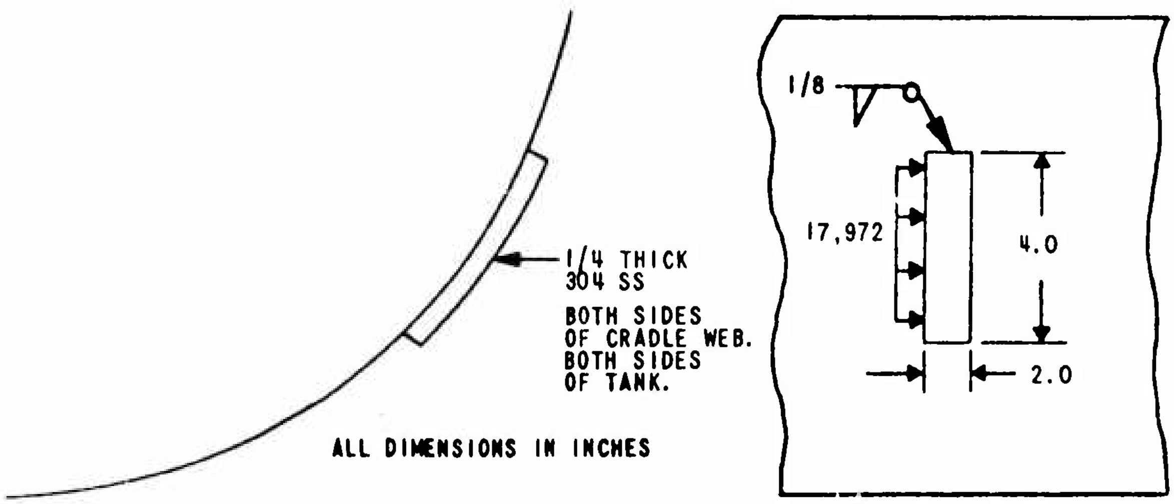
Load/bolt = 7660 pounds

Bolt strength = 9350 yield

$\underline{\underline{S.F. = 1.22}}$

HORIZONTAL LOAD BEARING

$$\text{Load/bearing pad} = \frac{35944}{2} = 17{,}972 \text{ pounds}$$



Weld Shear

Total of 10" weld fillet 1/8 fillet

Shear area = (10)(.125) = 1.25 inches

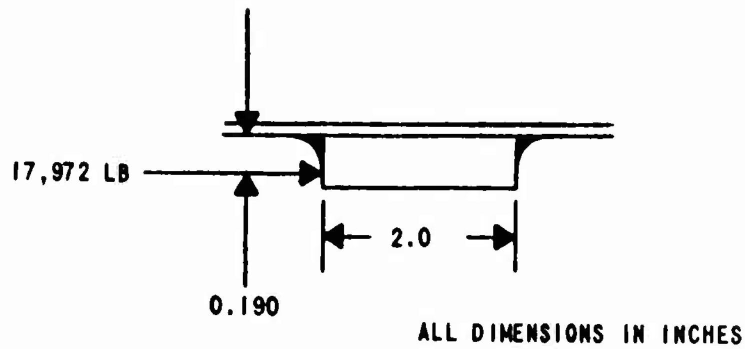
304ss σ yield = 30 kpsi

$\therefore$ ϵ yield = 15 kpsi

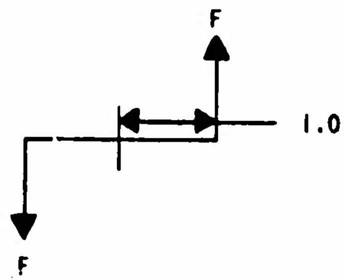
(1.25)(15 kpsi) = 18,750 pounds yield

S.F. yield = 1.04 crash conditions

TANK TEAROUT



Moment = (17,942)(.190) = 3408 in-lb



$$F = \frac{3408}{2} = 1704 \text{ pounds}$$

Weld Shear: 4" weld 1/8 fillet

$A = (4)(.125) = 0.50 \text{ in}^2$

(15K)(0.50) = 7500 pounds maximum load

$$SF = \frac{7500}{1704}$$

SF_{yield} = 4.4 @ Crash Condition

Skin Tear Out: 4" long x .078 wall = .312 in^2

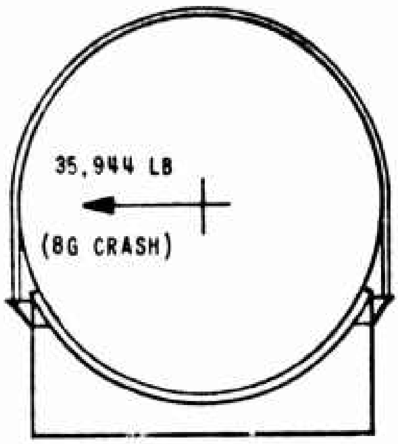
(.312)(15K) = 4.68K

$$SF = \frac{4.68K}{1.7\ K}$$

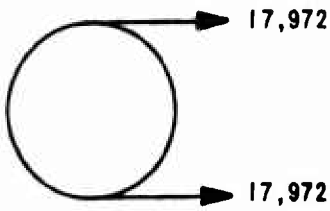
SF_{yield} = 2.75 @ Crash Condition

NOTE: All these calculations are based on conservative assumption that no friction exists at the pads.

LATERAL LOADING



Assume like:



SAME STRAP LOADS IF TANK PIVOTS AT BOTTOM

2 Straps at 8986

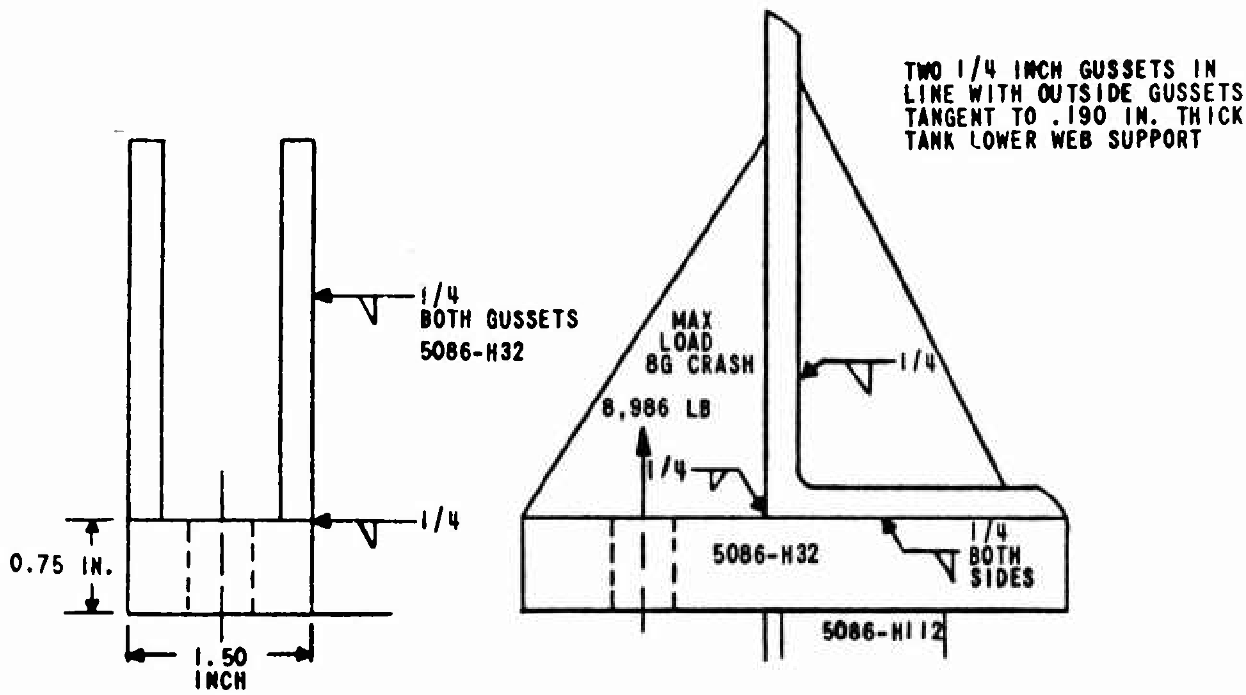
Strap Force = 8986

$SF = \frac{12000}{8986}$, $\underline{\underline{SF = 1.33 \text{ @ } 8g \text{ crash yield}}}$

Bolt Force = 8986

$SF = \frac{9350}{8986}$, $\underline{\underline{SF = 1.04 \text{ @ } 8g \text{ crash yield}}}$

STRAP BOLT ATTACHMENT



Shear: Area = 7" of 1/4" fillet weld + 3/4" 5083-HO (welded)

Area Weld = (7.0)(.707)(.25) = 1.24

Area Plate = (1.5)(.75) = 1.13

Allowable Load = (1.24)(3.5K) + (1.13)(8K)

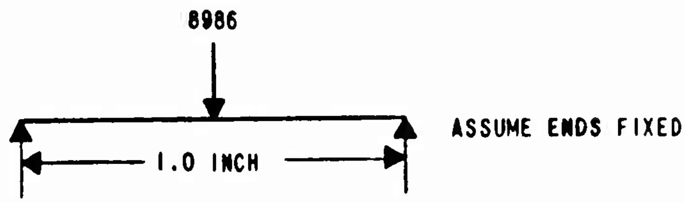
6061-TO ϵ_{yield} 5086-HO ϵ_{yield}

= 13,380 pounds

Actual Load = 8987

<u>S.F. = 1.4 on yield, @ 8g crash</u>

PLATE BENDING



$$M\,(\text{maximum}) = 1/8\ WL = (1/8)(8986)(1.0)$$

$$M\,(\text{maximum}) = 1123 \text{ in-lb}$$

$$I = \frac{bh^3}{12} = \frac{(2.0 - 0.5)(.75)^3}{12} = .0527 \text{ in}^4$$

Stress Concentration $K = 2.0$ (Page 613 Shigley)

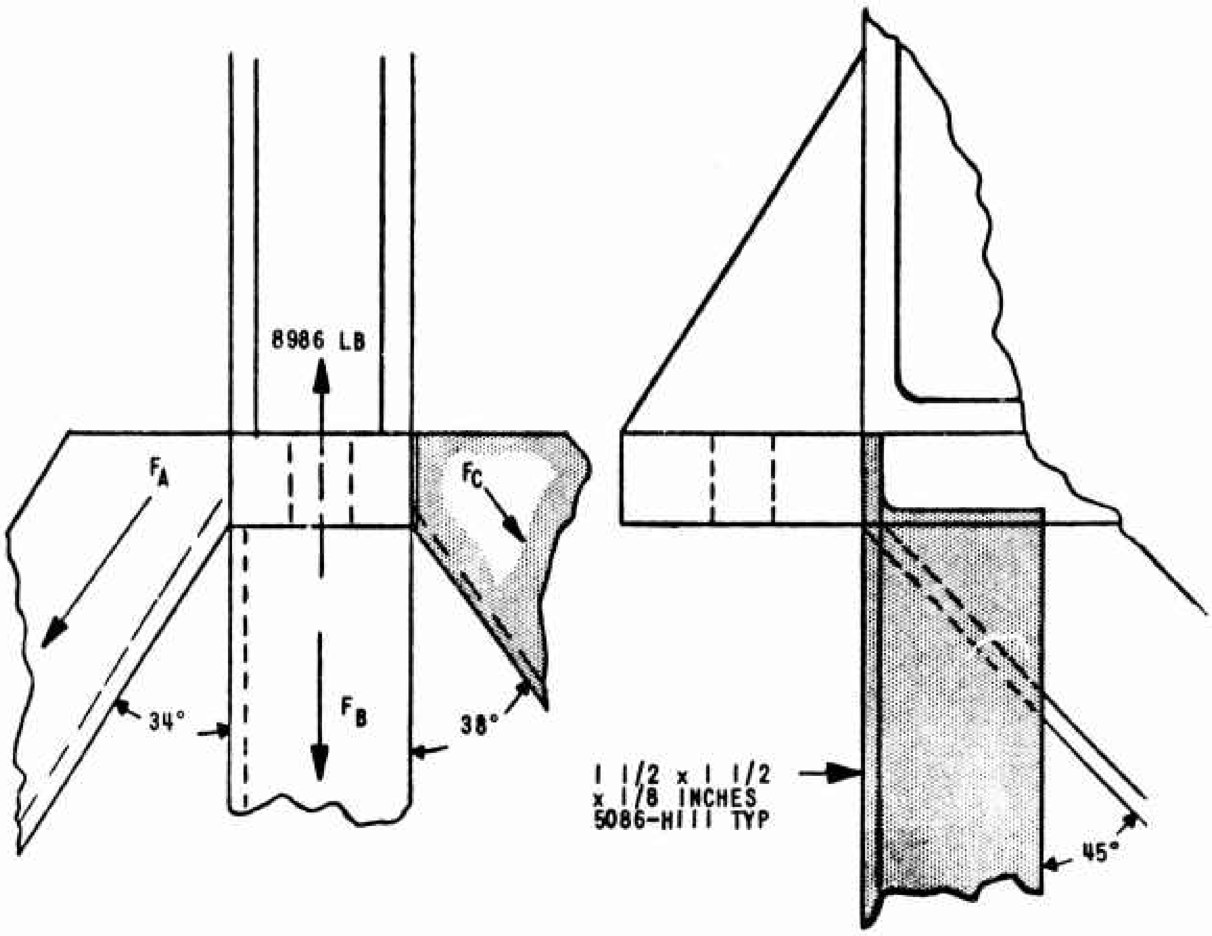
$$\sigma = K\frac{My}{I} = \frac{(2.0)(1123)(.375)}{.0527}$$

$$\sigma = 15{,}981$$

Material is 5086-H112, $\sigma_{ty} = 16K$

SF = 1.001 on 8g crash yield

ANGLE SUPPORTS



F_A cos 34° + F_B cos 45° + F_C cos 38° = 8986 pounds

F_A x .83 + F_B x .707 + F_Cx.787 = 8986 pounds

Assume load split evenly between the 3 members

$\therefore$ Load/Member = $\frac{8986}{3}$ = 2995 pounds

Worst Member is @ 45°

$\therefore$ Load = $\frac{2995}{.707}$

Load = 4237 pounds

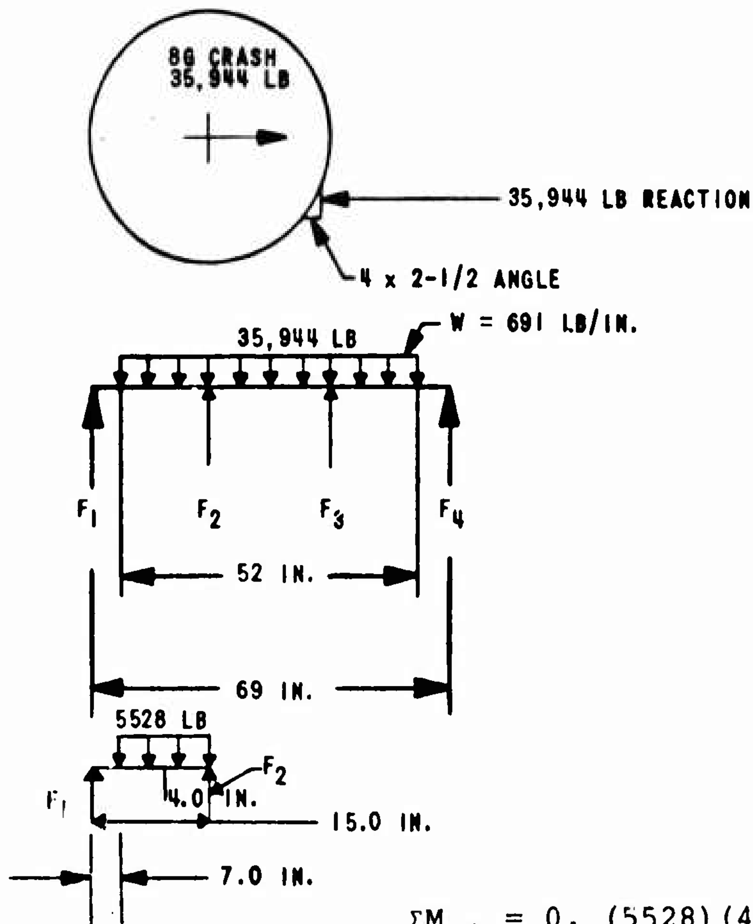
Tension: $A = 0.36\ in^2$

$\sigma = 11{,}769$ psi

5086-H112 $\sigma_{yield} = 14$ kpsi minimum (HO condition)

SF = 1.19 @ 8g crash
yield

CRADLE STRUCTURE - 8G SIDE LOADING



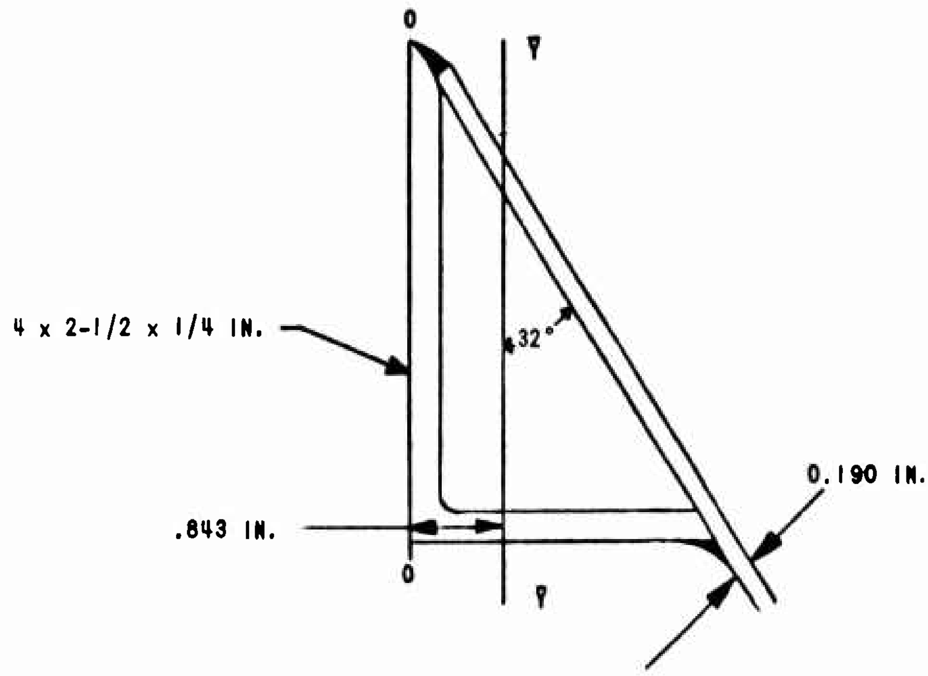
$\Sigma M_{F2} = 0,\ (5528)(4) = (F_1)(15)$

$F_1 = F_4 = 1474$ pounds

$\therefore\ F_2 = F_3 = 16{,}497$ pounds

Beam fixed at points F_1, F_2, F_3, and F_4.

Find beam failure point between F_2 and F_3.



Angle: $A_A = 1.58 \text{ in}^2$, $I_{yy} = 0.81$

Nt Axis @ 0.57

Plate: Area = (.190)(4.5) = 0.855 in²

Nt Axis @ 1.35

$\Sigma M_{OO} = 0 \quad (1.58)(0.57) + (.855)(1.35) = \bar{y}\ (2.435)$

$\underline{\bar{y} = 0.843}$

Angle $I_{\bar{y}\bar{y}} = 0.81 + (1.58)(.843 - .57)^2 = .9277$

Plate $I_{\overline{yy}} = \dfrac{(\frac{.190}{.522})(2.3)^3}{12} + (.855)(.843 - .775)^2 = \underline{0.3729}$

$\underline{Y = 1.80}$ $\qquad\qquad \underline{\underline{I_{BEAM} = 1.30 \text{ in}^4}}$

Distance between supports = 29.0

For beam in uniform loading of = 691 lb/in with fixed ends, moment in center of beam

$$M_{max} = (\frac{1}{24})(691)(29)^2$$

$$M_{max} = 24{,}213 \text{ in-lb}$$

$$\sigma = \frac{My}{I} = \frac{(24.213K)(1.8)}{1.30}$$

$$\underline{\sigma \text{ max} = 33{,}527 \text{ kpsi}}$$

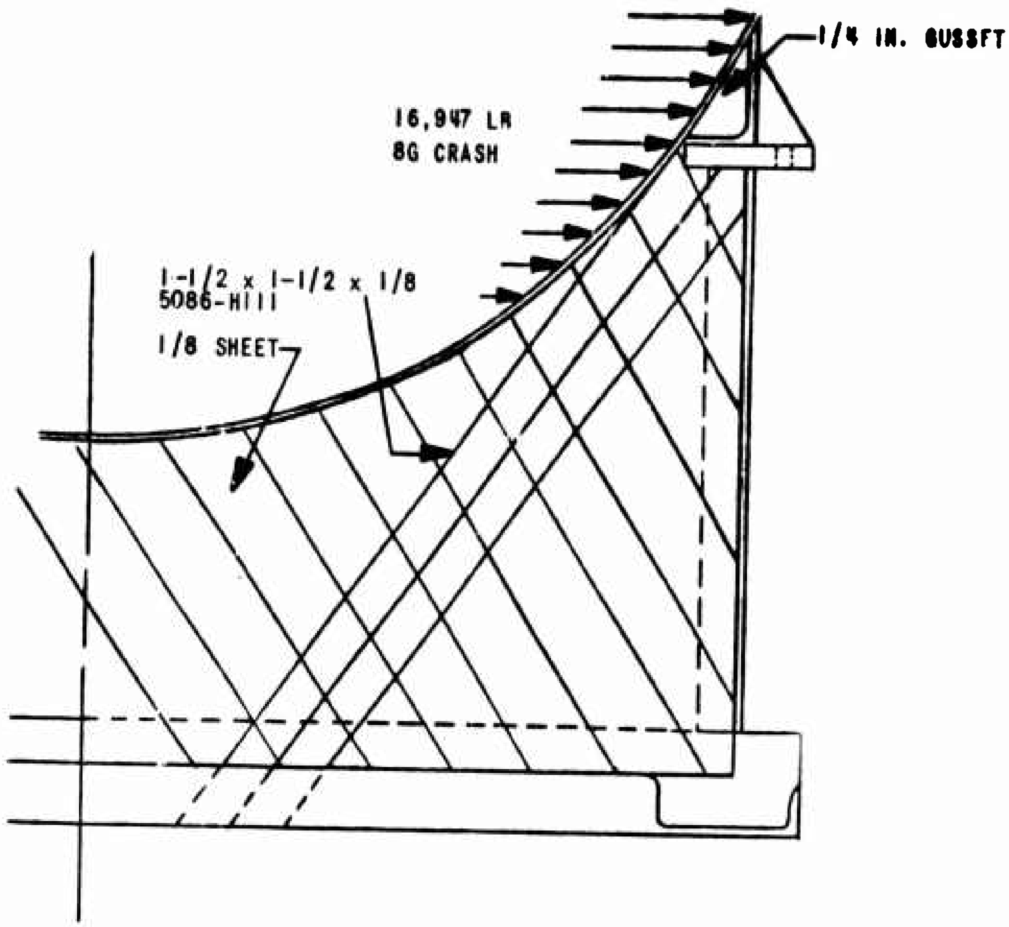
Material is 5086-H111 extrusion

$$\sigma_{ult} = 36 \text{ kpsi}$$

$$\underline{\underline{SF_{ult} = 1.07 \text{ 8g crash}}}$$

This is conservative since the tank was considered to add no strength.

STRENGTH AT SUPPORTS



Shear: Cannot shear since load puts 1-1/2 x 1-1/2 x 1/8 angle plus 1/8 sheet in tension.

Tension: Length of 1/8-inch plate needed to hold 16,947 pounds.

$$\sigma = \frac{F}{A} \qquad A = \frac{F}{\sigma}, \; L_{min} = \frac{F}{\sigma(.125)}$$

Sheet is 5086-H32

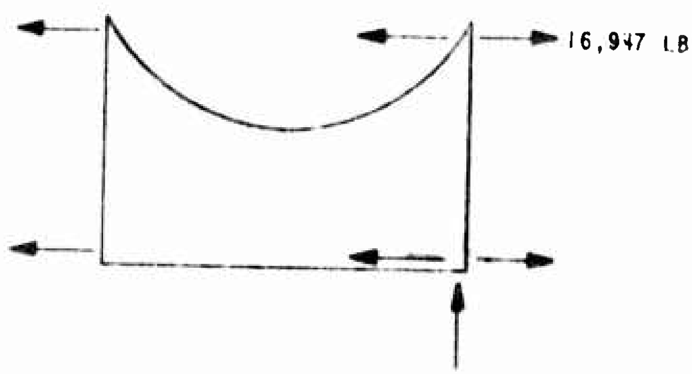
$$\sigma_{ult} = 40 \text{ kpsi}, \; L_{min} = \frac{16{,}947}{(40K)(.125)}$$

$$\underline{L_{min} = 3.38 \text{ inches}}$$

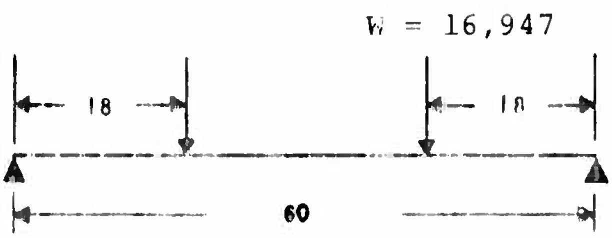
Obviously strong enough

LONGITUDINAL BEAM BENDING

The tank support chalks can be considered rigid members.



Assume load is carried equally by all four longitudinal members. This is conservative since cross-bracing structures actually distribute load.



ALL DIMENSIONS IN INCHES

$$\sigma = \frac{(W)(18)}{S}$$

where "S" is summary of all four longitudinal beams

$S = I/y$

Upper beams : $S = \frac{1.30}{1.80} \times 2 = 1.44$

Lower beams : $S = (3.00)(2) = \underline{6.00}$

$S_T = 7.44 \text{ in}^3$

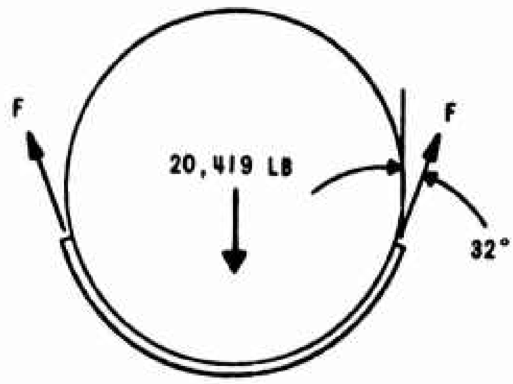
$$\sigma = \frac{(16947)(18)}{7.44}$$

$$\sigma = 41 \text{ kpsi}$$

$$\sigma_{ult} = 40 \text{ kpsi}$$

This is okay since cross-bracing and friction forces were neglected.

DOWNWARD G LOADING



Two cradle straps

$$\text{F} \cos 32° = \frac{20419}{2}$$

$$F = \frac{20419}{(4)(.847)} = 6026 \text{ pounds}$$

Assume 1/8 x 8 belly strap must support total 6026 pounds

$$\text{Tension:} \quad \sigma = \frac{F}{A} = \frac{6026}{(8)(1/8)}$$

$$\underline{\sigma = 6026 \text{ psi}}$$

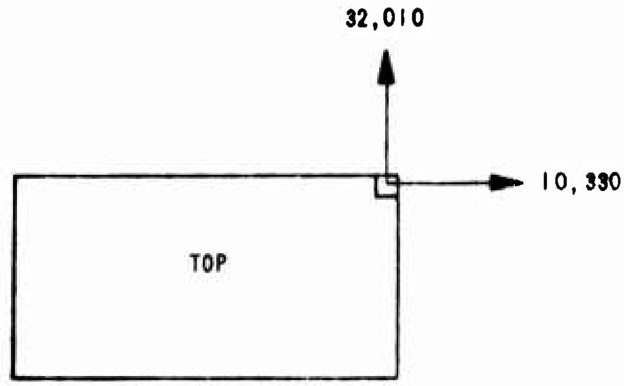
$$\sigma_{yld} = 28 \text{ kpsi}$$

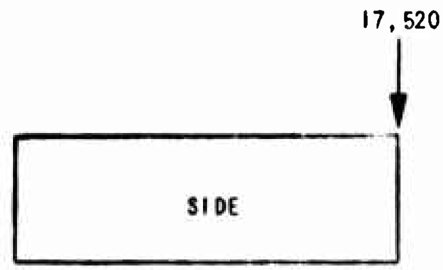
$$\underline{\underline{SF = 4.6}}$$

Entire chalk structure is overly strong.

TIE-DOWN LOADS

Maximum loads as determined by aero tie-downs:





VERTICAL COLUMN

Compressure load = 17,520 pounds

For pinned ends $P_{cr} = \dfrac{\pi^2 EI}{L^2}$

$$I_{min} = \frac{L^2 P_{cr}}{\pi^2 E} = \frac{(20)^2 (17,520)}{(\pi^2)(10.3 \times 10^6)}$$

$\underline{I_{min} = 0.0546}$

Beam is 3 x 3 x 3/16 < $I_{min} = 0.38$

$\underline{\underline{SF = 7.60}}$

$$\text{Compressure Stress} = \frac{17{,}520}{1.08} = 16{,}222 \text{ psi}$$

$$SF = \frac{18 \text{ yld comp.}}{16.2}\ , \quad \underline{\underline{SF = 1.11 \text{ yield}}}$$

END BEAMS

Tensile Load = 32,010 pounds

4 x 3 x 1/4 angle A = 1.69

σ = 18,940 psi

$$SF = \frac{21K}{18{,}940}\ , \quad \underline{\underline{SF = 1.11 \text{ yld}}}$$

LONGITUDINAL BEAMS

4 x 2-1/2 x 1/2 angle A = 1.58

$$\sigma = \frac{F}{A} = \frac{10{,}330}{1.58} = 6538 \text{ psi}$$

$$SF = \frac{21}{6.54}$$

$$\underline{\underline{SF = 3.21 \text{ yield}}}$$

WELD SHEAR (END ANGLE)

To break the weld, block must pull out of corner. Weld length in shear = 2.75 + 4.25 + 2.25 + 3.5

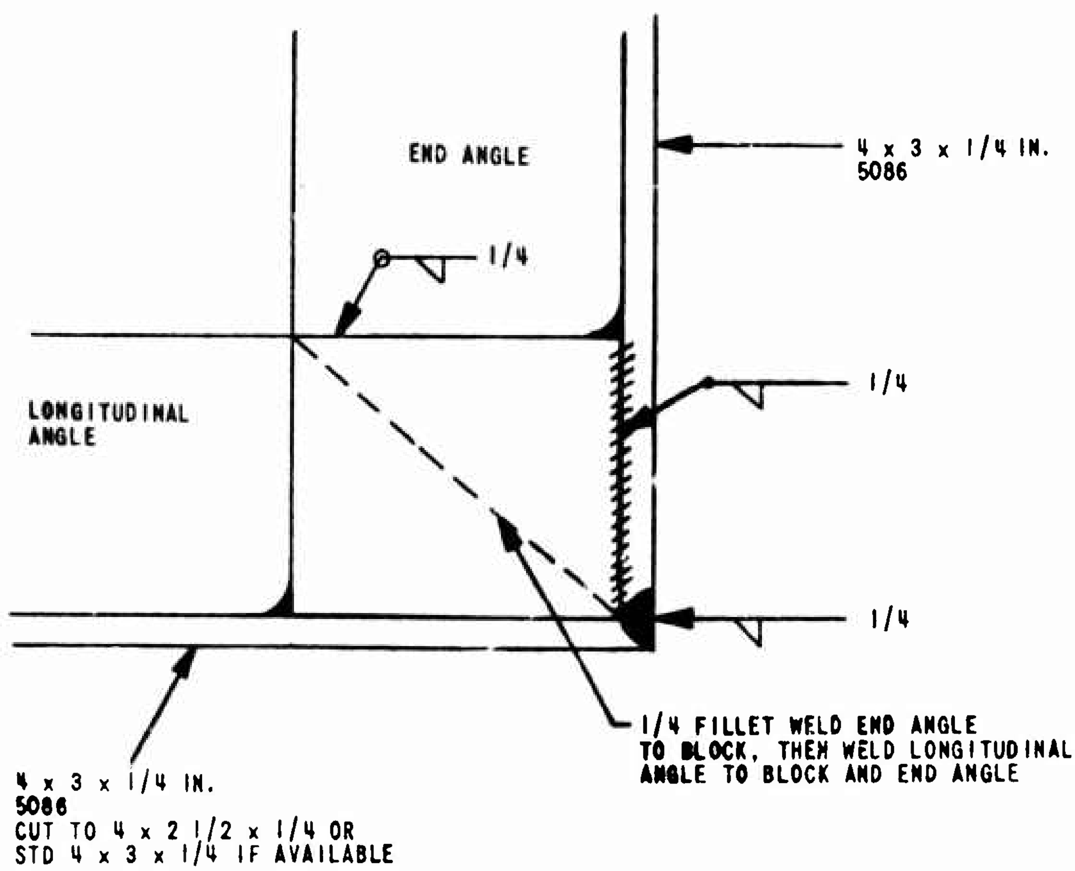
Shear length = 12.75 inches

1/4 Fillet ϵ_{ult} = 21 kpsi

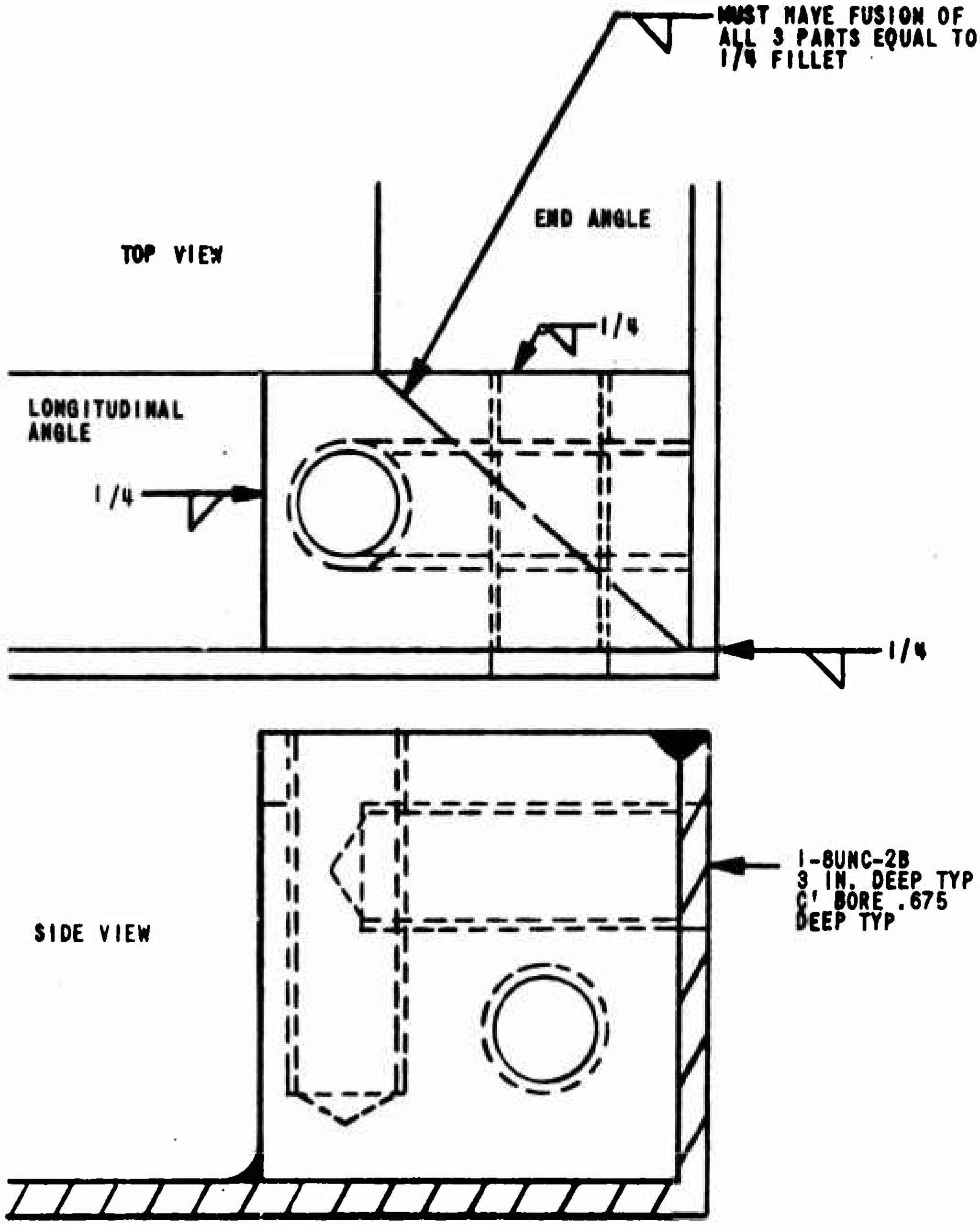
Strength = (.707)(.25)(12.75)(21K) = 47,320 pounds

Maximum load = 32,010

SF = 1.47 ult (crash @ 8g)



CORNER BLOCK DETAIL



EYE BOLTS

Use 3014T shoulder eye bolt 1-inch shank, 1-8UNC-2A thread 2-1/2-inch shank.

Macarco,

Ult load = 40,000 pounds

If the maximum load imposed is vector sum of maximum component loads,

Maximum load = 37,924 pounds

$$\underline{\underline{SF = 1.054 \text{ ult}}}$$

This is conservative since more than one tie-down will be used for the maximum load condition.

Also, maximum normal load = 3/8 crash load.

THREAD SHEAR

Thread is 1-8UNC-2B

Engagement = 1.90 inches minimum

$$\text{Shear area} = \left(\frac{15}{16}\right)(\pi)(50\%)(1.90) = 2.794 \text{ in}^2$$

Material is 5868H32 ϵ_{ult} = 25 kpsi

Maximum load permissible = 69,850 pounds

$$\underline{\underline{SF = 1.84 \text{ ult}}}$$

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UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) FMC Corporation/Defense Technology Laboratories P. O. Box 1201, 333 Brokaw Road San Jose, California 95108	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

PWU-5/A MODULAR INTERNAL SPRAY SYSTEM

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report - July 1969 to September 1971

5. AUTHOR(S) (First name, middle initial, last name)

Larry R. Ramsauer

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1972	194	

8a. CONTRACT OR GRANT NO. F08635-69-C-0213	9a. ORIGINATOR'S REPORT NUMBER(S) AFATL-TR-72-13
b. PROJECT NO. 5172	
c. Task No. 05	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d. Work Unit No. 000	AFATL-TR-72-13

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Available in DDC	Air Force Armament Laboratory Air Force Systems Command Eglin Air Force Base, Florida 32542

13. ABSTRACT

The PWU-5/A Modular Internal Spray System has been designed and developed to fit ten cargo/utility-type aircraft, including the C-47, C-54, C-123, and C-130. The system was designed to disseminate herbicides, pesticides, and fertilizers in chemical solution, suspension or slurry form, at ground deposition rates from 3 ounces/acre to 3 gallons/acre with a minimum swath width of 2 times the applicable aircraft wing span. The system is completely self-supporting, requiring no aircraft power, and includes provisions for suction filling, agent recirculation/agitation, dissemination, system flushing, aircraft washdown, and emergency dumping of the full agent payload. The system used aerospace adhesive to secure all external hardware, allowing system installation with minimal aircraft modification. A complete C-123K MISS was installed and flight tested at Eglin Air Force Base, Florida. The system was subjected to the complete flight envelope and functioned as designed. Flight test results indicated that manual operation of the emergency dump took too long to initiate. Also, the dump chute should be moved to the aft portion of the jump door to minimize emergency dump contamination and the right-hand fuselage spray station should be capped off to eliminate fuselage spray contamination.

DD FORM 1 NOV 65 1473

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Modular Internal Spray System						
Modular System						
Aircraft Spray Dissemination						
Herbicide Dissemination						
Pesticide Dissemination						
Fertilizer Dissemination						
Aircraft Modular System						
Internal Spray Tanks						
Cargo Aircraft Spray System						
Utility Aircraft Spray System						